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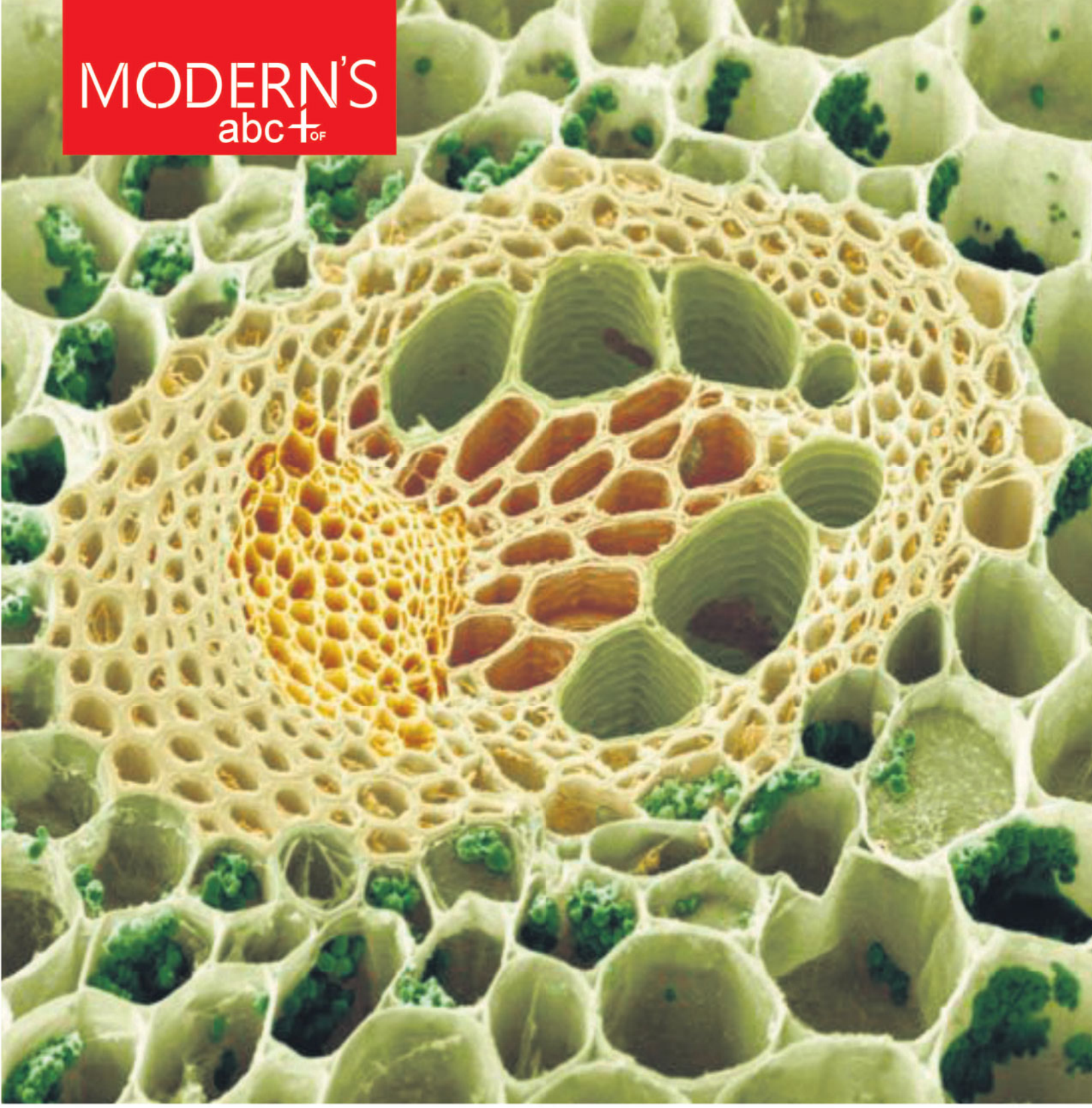

BIOLOGY

CLASS-XI

PART-I & II

STRICTLY ACCORDING TO THE NEW SYLLABUS

INDIA'S FIRST SMART BOOK

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Dr. B.B. Arora
A.K. Sabharwal

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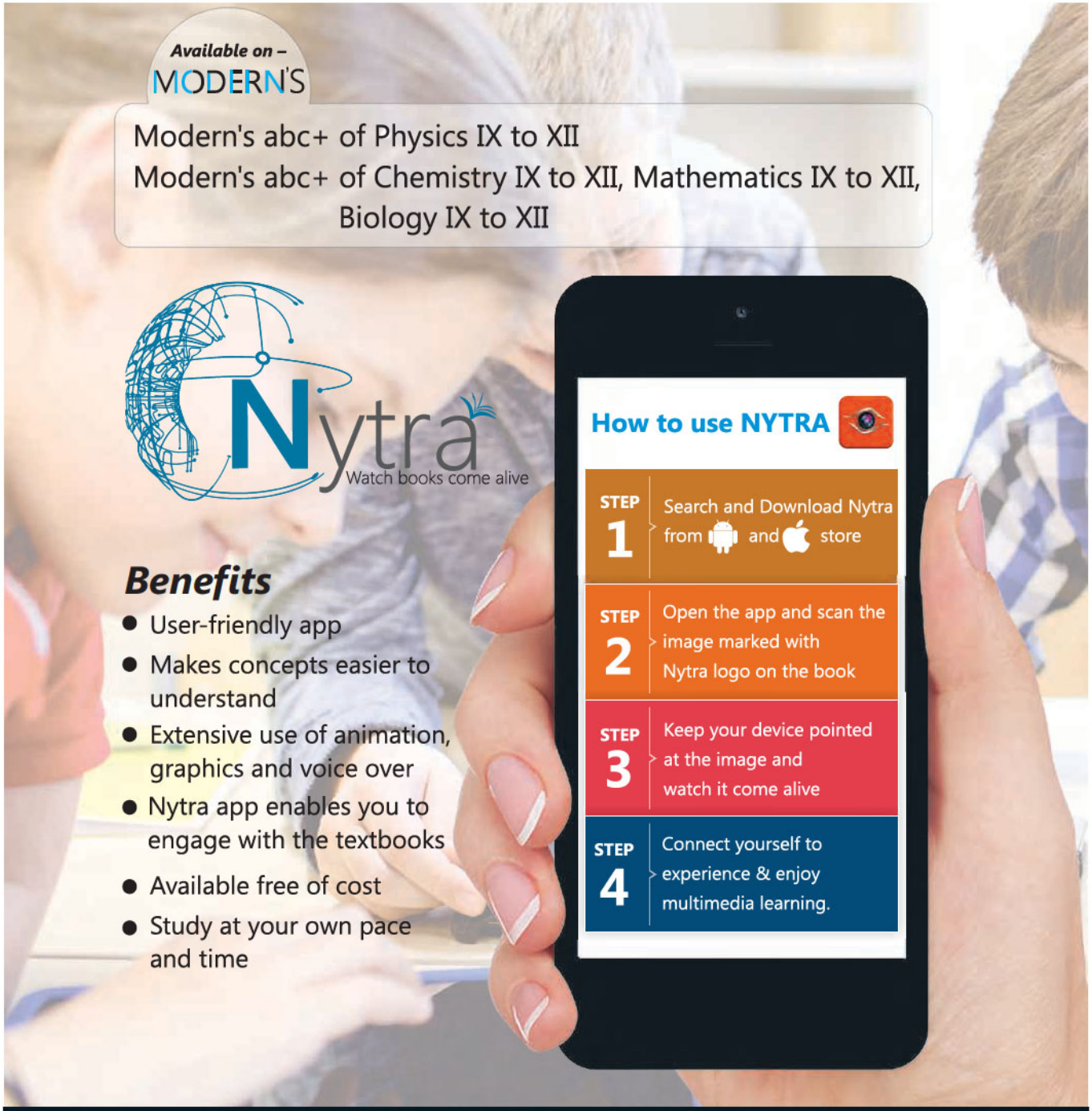

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According to new syllabus prescribed by Central Board of Secondary Education (CBSE), New Delhi and State Boards of Uttarakhand, Karnataka (1st Year PUC), Chhattisgarh, Jharkhand, Punjab, Haryana, Himachal, Kerala, Mizoram, Meghalaya, Nagaland, Assam, Manipur and other States following CBSE & ISC curriculum.

MODERN'S abc of

BIOLOGY

INDIA'S FIRST SMART BOOK

Class XI

PART-I

Strictly in accordance with the Latest Guidelines and Syllabus issued by N.C.E.R.T. / C.B.S.E.

By

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REVISED AND UPDATED EDITION 2019-2020

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- **Delhi (Patparganj):** Plot No. 225, Industrial Area — Ph. 22149691, 22147073

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Modern's abc of Practical Physics
Modern's abc + of Chemistry
Modern's abc of Practical Chemistry
Modern's abc + of Biology
Modern's abc of Practical Biology
Modern's abc + of Mathematics
Solutions of Modern's abc of Mathematics
Modern's abc of Computer Science C++

FOR JEE-Main, JEE-Advance & Medical (NEET)

Modern's abc of Objective Physics
Modern's abc of Objective Chemistry
Modern's abc of Objective Mathematics
Modern's abc of Objective Biology

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Preface

We feel pleasure in presenting the revised edition of our book "Modern's abc + of Biology" for class XI students. The book has been prepared strictly according to the new syllabus proposed by CBSE New Delhi and Education Board of other Indian states and N.C.E.R.T. textbook.

About the book :

Before you begin working from this book, it would be a good idea to have a look at the way it has been written.

The Text :

The most important word in the study of Biology is 'Understanding of Text'. In writing this book, we have kept this fact in mind and have tried to explain the basic ideas as clearly as possible. Technical terms have been explained under the heading 'New Terms'. Well drawn and accurate self explanatory diagrams provide further help in understanding the contents of the book.

Several comparative tables have been incorporated in the text to highlight the important differences between important concepts at a glance.

Noteworthy features :

- NCERT Textbook Questions Solved
- NCERT Exemplar Problems Solved

Solutions of Important questions are given at the end of every chapter.

Special emphasis has been given to narrative style, illustrations, coverage of topics and clarity of expression.

Extension Boxes :

Extension boxes have been given in the text to get a wider understanding of the subject. Extension boxes are available in two forms :

- The boxes which provide extra information about the topic.
- The boxes which contain some Interesting Facts about Competitive Examinations.

Test Questions :

Test questions have been categorised under the following heading :

A. Practice Problems. Solved practice problems have been included at a number of places in each other to revise the text.
B. Multiple Choice Questions. Questions from various competitive examinations are included. This will help you to test your comprehension against all sorts of subject problems that will come up in your examination.
C. Fill in the Blanks.
D. Match the Words/Sentences
E. True or False
F. Reasoning Type Questions (For AIIMS aspirants)
G. Assertion Type Questions (For AIIMS aspirants)
H. HOTS Questions

Text questions have been further classified into :

- Very Short Answer Questions (One mark each)
- Short Answer Questions (Two marks each)
- Short Answer Questions (Three marks each)
- Long Answer Questions (Five marks each)

We have included the answers at the end of each chapter. Most of the questions are straight-forward and can be attempted from the information provided in the book.

This 'SMART BOOK' is being presented after microscopic revision. Each and every word has been read with utmost care. Being a smart book, it is incorporated with "NYTRA", which is the first augmented reality app. for K-12 Education in India. NYTRA will facilitate the readers to understand the basics and the allegorical background of the subject matter very easily and clearly with the help of different laminations.

Acknowledgements :

We are highly thankful to Modern Publishers for his valuable support throughout the making of this book. We should like to express our gratitude to Mr. Manik Juneja, Director-Content & Production, Mr. B. S. Rawat, Mr. S. K. Sikka and Mr. Ravinder Pathania for their help and cooperation to prepare the project. The book is bound to prove highly useful for various medical, dental and other competitive entrance tests. Suggestions for improvement of this book will be always welcomed.

—Dr. B.B. Arora

—Ashok Sabharwal

SOME IMPORTANT SCIENTISTS IN BIOLOGY AND RELATED FIELDS

1.	Father of Biology	:	Aristotle
2.	Father of Botany	:	Theophrastus
3.	Father of Zoology	:	Aristotle
4.	Father of Plant Physiology	:	Stephan Hales
5.	Father of Taxonomy	:	Carl Linnaeus
6.	Father of Genetics	:	G. J. Mendel
7.	Father of Experimental Genetics	:	Morgan
8.	Father of Bryology	:	Johann Hedwig
9.	Father of Modern Cytology	:	Carl P. Swanson
10.	Father of Microscopy	:	Marcello Malpighi
11.	Father of Comparative Anatomy	:	Bason George Cuvier
12.	Father of Modern Anatomy	:	Andreas Vesalius
13.	Father of Experimental Physiology	:	Galen
14.	Father of Study of Circulation of Blood	:	William Harvey
15.	Father of Evolutionary Ideas	:	Empedocles
16.	Father of Eugenics	:	F. Galton
17.	Father of Modern Embryology	:	K.V. Baer
18.	Father of Ayurveda	:	Charaka
19.	Father of Palaeontology	:	L. da Vinci
20.	Father of Medicine	:	Hippocrates
21.	Father of Indian Mycology	:	E.J. Butler
22.	Father of Bacteriology	:	Robert Koch
23.	Father of Microbiology	:	Louis Pasteur
24.	Father of Mutation	:	Hugo de Vries
25.	Father of Special Creation Theory	:	Father Saurez
26.	Father of Immunology	:	Edward Jenner
27.	Father of Modern Genetics	:	Bateson
28.	Father of Blood Groups	:	C. Landsteiner
29.	Father of Indian Taxonomy	:	Santapau

SOME INTERESTING PLANTS

1.	Smallest flower	—	Wolffia (0.1 mm)
2.	Smallest parasite	—	Arceutaopium
3.	Largest chromosome	—	Trillium – 30.0μ
4.	Smallest chromosome	—	Algae – 0.025μ
5.	Largest number of chromosomes	—	2n = 1262 Ophioglossum (a pteridophyte)
6.	Minimum number of chromosomes	—	2n = 4 Haplopappus gracilis
7.	Oldest plant	—	Larrea tridentata (S.W. California—U.S.A.) 11,300 years
8.	Fastest growing plant	—	Hespiroyucca whipplei (Liliaceae) (grows 12 ft. in 14 days)
9.	Plants reported at maximum elevation	—	Can grow upto 25,447 ft. above sea level
	(a) Ernania himalayeansis		
	(b) Ranunculus lobatus		
10.	Plant producing smallest seed	—	Orchids
11.	Plant with largest egg cell and antherozoid	—	Cycas
12.	Biggest ovule	—	Cycas
13.	Smallest cell	—	Mycoplasma gallisepticum (PPLO)
14.	Largest plant cell	—	Acetabularia (a green algae)
15.	Indian National flower	—	Nelumbium (lotus)
16.	Heaviest timber	—	Olea laurifloia
17.	Lightest timber	—	Acrometo gonus
18.	Hardest wood	—	Hardwickia
19.	Tallest Angiosperm	—	Eucalyptus – 114 metre
20.	Tallest Gymnosperm	—	Sequoia sempervirens – 111.25 metre
21.	Smallest Angiospermic plant	—	Wolffia
22.	Smallest Gymnosperm	—	Zamia pygmea
23.	Smallest Pteridophyta	—	Azolla
24.	Biggest bacterium	—	Epulopisicum fishelsoni, 1/2 mm
25.	Plant with largest flower	—	Rafflesia
26.	Plant with largest leaves	—	Victoria regia
27.	Plant producing largest fruit	—	Lodoicea

NOBEL PRIZE WINNERS — PHYSIOLOGY OR MEDICINE

1901	Emil von Behring
1902	Sr Ronald Ross
1903	Niels Finsen
1904	Ivan Pavlov
1905	Robert Koch
1906	Camilio Golgi and Santiago Ramony Cajal
1907	Charles Laveran
1908	Paul Ehrilch and Elie Metchnikoff
1909	Emil Theodor Kocher
1910	Albrecht Kossel
1911	Allvar Gullstrand
1912	Alexis Carrel
1913	Charles Richet
1914	Robert Barany
1915-18	No award
1919	Jules Bordet
1920	August Krogh
1921	No award
1922	Archibald Hill and Otto Meyerhof
1923	Sir Frederick Banting and John Macleod
1924	Willem Einthoven
1925	No award
1926	Johannes Fibiger
1927	Julius Wagner-Jauregg
1928	Charles Nicolle
1929	Christmas Eijkman and Sir Frederick Hopkins
1930	Karl Landsteiner
1931	Otto Warburg
1932	Edgar Adrian and Sir Charles Sherrington
1933	Thomas H. Morgan
1934	George Minot, William P. Murphy and George Whipple
1935	Hans Spemann
1936	Sir Henry Dale and Otto Loewi
1937	Albert Szent Gyoigyi
1938	Corneille Heymans
1939	Gerhard Domagk-declined
1943	Henrik Dam and Edward Doisy
1944	Joseph Erlanger and Herbert Gasser
1945	Sir Alexander Fleming, Howard Florey and Emst Chain
1946	Herman Muller
1947	Carl and Gerty Cori and Bernardo Houssay
1948	Paul Muller
1949	Walter Hess and Antonio Moniz
1950	Philip Hench, Edward Kendal and Tadeus Reichstein
1951	Max Theiler
1952	Selman Waksman
1953	Fritz Lipman and Hans Krebs
1954	John Enders, Thomas Weller and Fredrick Robbins
1955	Hugo Theorell
1956	Andre Cournand, Dickinson Richards Jr. and Werner Forssmann
1957	Daniel Bovet
1958	George Beadle, Edward Tatum and Joshun Lederberg
1959	Severo Ochoa and Arthur Kornberg
1960	Sir Macfarlene Burnet and Peter Medawar
1961	Georg von Bekesy
1962	Francis Crick, Maruice Wilkins and James Watson
1963	Alan Hodgkin, Andrew Huxley and Sir John Ecdes
1964	Konrad Bloch Feodor Lynen
1965	Francois Jacob, Andre Lwoff and Jacques Monod
1966	Charles Huggins and Francis Rous
1967	Ragner Granit, Haldan Hartline and George Wald
1968	Robert Holley, Har Gobind Khorana and Marshal Nirenberg
1969	Max Delbruck, Alfred Hershey and Salvador Luria
1970	Sir Bernard Katz, Ulf von Euler and Julius Axelrod
1971	Earl Sutherland Jr.
1972	Rodney Porter and Gerald Edelman
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1985	Michael Brown and Joseph Goldstein
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1987	Susumu Tonegawa
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1990	Donnal E. Thomas and Joseph Murray

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1992	Edmund Fisher and Edwin Krebs
1993	Richard J. Robers and Philips A. Sharp
1994	Alfred Gilman and Martin Rodkil
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1996	Peter C. Doherty
1997	Stanleg Prusiner
1998	Robert F. Furchgott, Louis J. Ignaro and Farid Murad
1999	Gunter Blobel
2000	A. Carrison, Paul Greengard and Eric Kandel
2001	L. Hartwell, Timothy Hunt and Paul Nurse
2002	Sydney Brenner, H. Robert Howvitz and John E.Sulzton
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2009	Elizabeth Blackburn, Carol Greider and Jack Szostak
2010	Professor Robert G. Edwards
2011	Bruce A. Beutler, Jules A. Hoffmann and Ralph M. Steinman
2012	Sir John B. Gurdon and Shinya Yamanaka
2013	James E. Rothman, Randy W. Schekman and Thomas C. Sudhof
2014	John O'keefe, May-Britt Moser and Edvard I. Moser
2015	William C. Campbell, Satoshi Omura and Youyou Tu
2016	Yoshinori Ohsumi
2017	US geneticists Jeffrey C. Hall, Michael Rosbash and Michael W. Young for revealing the role of genes in setting the circadian clock'.
2018	James P. Allison and Tasuku Honjo "for their discovery of cancer therapy by inhibition of negative immune regulation."

IMPORTANT DATES

Date and Month	Important as
30th January	Antileprosy Day
1st week of February and July	Van Mahotsav
28th February	National Science Day
15th March	World Handicap Day
21st March	World Forest Day
24th March	World Tuberculosis Day
7th April	World Health Day
11th April	Safe Motherhood Day
22nd April	World Earth Day
8th May	World Red Cross Day, Thalassemia Day
31st May	World No-Tobacco Day
5th June	World Environment Day
26th June	International Anti-Drug Day
11th July	World Population Day
Ist week of August	World Breast Feeding Week
6th August	Hiroshima and Nagasaki Day
20th August	Malaria Day
29th August	Mosquito Day
16th September	Ozone Day
Ist week of October	World Wildlife Week
1st October	Blood Donation Day
3rd October	World Animal Day
4th October	World Habitat Day
10th October	World Mental Health Day
16th October	World Food Day
14th November	World Diabetes Day
1st December	World AIDS Day
2nd December	National Pollution Prevention Day (Bhopal Tragedy Day)
3rd December	World Conservation Day
10th December	Human Rights Day
23rd December	Kisan Divas
29th December	International Day for Biological Diversity

DOCTRINES AND THEORIES IN BIOLOGY

Theory/Doctrine	Proposed by
Apical Cell Theory of Apical meristems	Hofmeister
Artificial system of classification	Aristotle
Axial gradient Theory	Child
Biogenesis (= Theory of movement)	Robert Brown
Biological Species Concept	Dobzensky and Meyer
Binomial nomenclature	Linnaeus
'Birds are glorified reptiles'	Huxley
Cascade effect	Sutherland
Cell Theory	Schleiden and Schwann
Central Dogma of Molecular Genetics	Crick
Chemosynthetic Theory	Oparin
Chromosomal Theory of Linkage	Morgan and Castle
Chromosomal Theory of Inheritance	Sutton and Boveri
Cohesion Theory of Ascent of Sap	Dixon and Jolly
Conditioned Reflex	I.P. Pavlov
Cosmozoic Theory	Richter
Coupling and Repulsion Theory	Bateson and Punnet
Descent with modification	Darwin
Discovery of Honeybee dance	Von Frisch
Double fertilization of Angiosperms	Nawaschin and Guingard
Five Kingdom Classification	Whittaker
Fluid Mosaic Model	Singer and Nicholson
Histogen Theory of Apical meristem	Hanstein
Gene Theory (Linkage of genes)	Morgan
Germplasm Theory	Weissmann
Germ Theory of disease	L. Pasteur
Genic Balance Theory of sex determination	C.B. Bridges
Induced fit Hypothesis of enzyme	Koshland
Idea of Homeostasis	Claude Bernard
Law of conservation of energy	Von Mayer
Life comes from life (proved by)	Francesco Redi
Lock and Key Hypothesis	Emil Fischer
Materialistic Theory	Oparin
Mutation Theory	Hugo de Vries
Nurse Culture technique (Cellular totipotency)	Muir et. al.
Omnis cellula e cellula	Rudolf Virchow
One cistron–one polypeptide Theory	C. Yanofsky
One gene–one enzyme Theory	Beadle and Tatum
Ontogeny recapitulates Phylogeny	E. Haeckel
Operon Concept of Gene action	Jacob and Monod
Organic evolution	Darwin and Wallace
'Protoplasm is the Physical basis of Life'	Huxley
Protoplasm Theory	Hertwig
Protoplasmic Theory	M. Schultze
Recapitulation Theory	Von Bear

Sol gel Theory of Amoeba Locomotion	Hyman, Pantin and Mast
Stellar Theory of Plants	Tiegham and Douliot
Survival of the fittest	Spencer
Telome Theory of Pteridophyta	Zimmermann
Theory of Abiogenesis	Helmont
Theory of Acquired characters	Lamarck
Theory of Artificial parthenogenesis	Loeb
Theory of Biogenetic Law	E. Haeckel
Theory of Catastrophism	Cuvier
Theory of Contagion	Fracastorius
Theory of Epigenesis	Wolff
Theory of Natural Selection	Charles Darwin
Theory of Opsonisation	Wright and Doughlass
Theory of Pangenesis	C. Darwin
Theory of Special Creation	Father Saurez
Tunica Corpus Theory	Schmidt
Vital Theory	J. C. Bose

SYLLABUS

BIOLOGY

CLASS XI (THEORY)

Time: 3 Hours Max. Marks: 70

Unit	Title	No. of Periods	Marks
1.	Diversity of Living Organisms	23	07
2.	Structural Organisation in Animals and Plants	22	12
3.	Cell: Structure and Function	35	15
4.	Plant Physiology	40	18
5.	Human Physiology	40	18
	Total	**160**	**70**

UNIT-I: DIVERSITY OF LIVING ORGANISMS (23 Periods)

Chapter-1: The Living World

- What is living? Biodiversity; Need for classification; Three domains of life; Taxonomy & Systematics; Concept of species and taxonomical hierarchy; Binomial nomenclature; Tools for study of Taxonomy– Museums, Zoological parks, Herbaria, Botanical gardens.

Chapter-2: Biological Classification

- Five kingdom classification; Salient features and classification of Monera; Protista and Fungi into major groups; Lichens; Viruses and Viroids.

Chapter-3: Plant Kingdom

- Salient features and classification of plants into major groups-Algae, Bryophyta, Pteridophyta, Gymnospermae and Angiospermae (three to five salient and distinguishing features and at least two examples of each category); Angiosperms-classification up to class, characteristic features and examples.

Chapter-4: Animal Kingdom

- Salient features and classification of animals-non chordates up to phyla level and chordates up to class level (three to five salient features and at least two examples of each category).
  (No live animals or specimen should be displayed).

UNIT -II: STRUCTURAL ORGANISATION IN ANIMALS AND PLANTS (22 Periods)

Chapter-5: Morphology of Flowering Plants

- Morphology and modifications: Internal Morphology of different parts of flowering plants; root, stem, leaf, inflorescence, flower, fruit and seed (To be dealt along with the relevant experiment of the Practical Syllabus).

Chapter-6: Anatomy of Flowering Plants

- Anatomy and functions of different tissues.

Chapter-7: Structural Organisation in Animals

- Animal tissues: Morphology, anatomy and functions of different systems (digestive, circulatory, respiratory, nervous and reproductive) of an insect (cockroach). (a brief account only)

UNIT-III: CELL: STRUCTURE AND FUNCTION (35 Periods)

Chapter-8: Cell-The Unit of Life

- Cell theory and cell as the basic unit of life: Structure of prokaryotic and eukaryotic cells; Plant cell and animal cell; Cell envelope, cell membrane, cell wall; Cell organelles, structure and function; Endomembrane system, endoplasmic reticulum, Golgi bodies, lysosomes, vacuoles; mitochondria, ribosomes, plastids, microbodies; Cytoskeleton, cilia, flagella, centrioles (ultrastructure and function); Nucleus, nuclear membrane, chromatin, nucleolus.

Chapter-9: Biomolecules

- Chemical constituents of living cells: Biomolecules, structure and function of proteins, carbohydrates, lipid, nucleic acids; enzymes, types, properties, enzyme action.

Chapter-10: Cell Cycle and Cell Division

- Cell cycle, mitosis, meiosis and their significance.

UNIT-IV : PLANT PHYSIOLOGY (40 Periods)

Chapter-11: Transport in Plants

- Movement of water, gases and nutrients; Cell to cell transport–Diffusion, facilitated diffusion, active transport; plant–water relations, Imbibition, water potential, osmosis, plasmolysis; Long distance transport of water–Absorption, apoplast, symplast, transpiration pull, root pressure and guttation; Transpiration–opening and closing of stomata; Uptake and translocation of mineral nutrients– Transport of food, phloem transport, Mass flow hypothesis; Diffusion of gases.

Chapter-12: Mineral Nutrition

- Essential minerals, macro and micronutrients and their role; deficiency symptoms; Mineral toxicity; Elementary idea of Hydroponics as a method to study mineral nutrition; Nitrogen metabolism-Nitrogen cycle, biological nitrogen fixation.

Chapter-13: Photosynthesis in Higher Plants

- Photosynthesis as a mean of Autotrophic nutrition; Site of photosynthesis; Pigments involved in photosynthesis (elementary idea); Photochemical and biosynthetic phases of photosynthesis; cyclic and non-cyclic photophosphorylation; Chemiosmotic hypothesis; photorespiration; C_3 and C_4 pathways; factors affecting photosynthesis.

Chapter-14: Respiration in Plants

- Exchange of gases; cellular respiration–glycolysis, fermentation (anaerobic), TCA cycle and electron transport system (aerobic); energy relations–Number of ATP molecules generated; Amphibolic pathways; Respiratory quotient.

Chapter-15: Plant - Growth and Development

- Seed germination; Phases of plant growth and plant growth rate; Conditions of growth; Differentiation, dedifferentiation and redifferentiation; Sequence of developmental processes in a plant cell; Growth regulators–auxin, gibberellin, cytokinin, ethylene, ABA; Seed dormancy; Vernalisation; Photoperiodism.

UNIT-V : HUMAN PHYSIOLOGY (40 Periods)

Chapter-16: Digestion and Absorption

- Alimentary canal and digestive glands, Role of digestive enzymes and gastrointestinal hormones; Peristalsis, digestion, absorption and assimilation of proteins, carbohydrates and fats; Calorific values of proteins, carbohydrates and fats; Egestion; Nutritional and digestive disorders–PEM, indigestion, constipation, vomiting, jaundice, diarrhoea.

Chapter-17: Breathing and Exchange of Gases

- Respiratory organs in animals (recall only); Respiratory system in humans; Mechanism of breathing and its regulation in humans–Exchange of gases, transport of gases and regulation of respiration, Respiratory volume; Disorders related to respiration-Asthma, Emphysema, Occupational respiratory disorders.

Chapter-18: Body Fluids and Circulation

- Composition of blood, blood groups, coagulation of blood; Composition of lymph and its function; Human circulatory system–Structure of human heart and blood vessels; Cardiac cycle, cardiac output, ECG; Double circulation; Regulation of cardiac activity; Disorders of circulatory system-Hypertension, Coronary artery disease, Angina pectoris, Heart failure.

Chapter-19: Excretory Products and Their Elimination

- Modes of excretion–Ammonotelism, ureotelism, uricotelism; Human excretory system–structure and function; Urine formation, Osmoregulation; Regulation of kidney function–Renin-angiotensin, Atrial Natriuretic Factor, ADH and Diabetes insipidus; Role of other organs in excretion; Disorders-Uraemia, Renal failure, Renal calculi, Nephritis; Dialysis and artificial kidney.

Chapter-20: Locomotion and Movement

- Types of movement–ciliary, flagellar, muscular; Skeletal muscle–contractile proteins and muscle contraction; Skeletal system and its functions; Joints; Disorders of muscular and skeletal system-Myasthenia gravis, Tetany, Muscular dystrophy, Arthritis, Osteoporosis, Gout.

Chapter-21: Neural Control and Coordination

- Neuron and nerves; Nervous system in humans–central nervous system, peripheral nervous system and visceral nervous system; Generation and conduction of nerve impulse; Reflex action; Sensory perception; Sense organs; Elementary structure and function of eye and ear.

Chapter-22: Chemical Coordination and Integration

- Endocrine glands and hormones; Human endocrine system-Hypothalamus, Pituitary, Pineal, Thyroid, Parathyroid, Adrenal, Pancreas, Gonads; Mechanism of hormone action (Elementary Idea); Role of hormones as messengers and regulators, Hypo-and hyperactivity and related disorders, dwarfism, acromegaly, cretinism, goiter, exophthalmic goiter, diabetes, Addison's disease.

  Note : Diseases related to all the human physiological systems to be taught in brief.

FATHERS IN THE FIELD OF BIOLOGY

Father of Biology	:	Aristotle
Father of Botany	:	Theophrastus
Father of Zoology	:	Aristotle
Father of Bacteriology	:	Robert Koch
Father of Plant Physiology	:	Stephan Hales
Father of Taxonomy	:	Carl Linnaeus
Father of Genetics	:	G. J. Mendel
Father of Experimental Genetics	:	Morgan
Father of Modern Cytology	:	Carl P. Swanson
Father of Plant Anatomy	:	N. Grew
Father of Mycology	:	Michcli
Father of Palynology	:	Erdtman
Father of Eugenics	:	Francis Galton
Father of Biochemical Genetics	:	Archibald Garrod
Father of DNA finger printing	:	Alec Jaffery
Father of Endocrinology	:	Addison
Father of ATP cycle	:	Lipmann
Father of Indian Ecology	:	R. Mishra
Father of Comparative Anatomy	:	Bason George Cuvier
Father of Modern Anatomy	:	Andreas Vesalius
Father of Experimental Physiology	:	Galen
Father of Eugenics	:	F. Galton
Father of Modern Embryology	:	K. V. Baer
Father of Ayurveda	:	Charaka
Father of Palaeontology	:	L. da Vinci
Father of Medicine	:	Hippocrates
Father of Indian Mycology	:	E. J. Butler
Father of Microbiology	:	Louis Pasteur
Father of Mutation	:	Hugo de Vries
Father of Immunology	:	Edward Jenner
Father of Modern Genetics	:	Bateson
Father of Blood groups	:	C. Landsteiner
Father of Genetic Engineering	:	Paul Berg
Father of Biochemistry	:	Leibig
Father of ECG	:	Einthoven
Father of Conditioned Reflex	:	Pavlov
Father of Plant Pathology	:	de Bary
Father of Antibiotics	:	Alexander Flemming
Father of Radiation Genetics	:	H. J. Muller
Father of Chemotherapy	:	Paul Enrich
Father of Virology	:	Stanley

IMPORTANT SYMBOLS & ABBREVIATIONS

Ala	:	Aristotle
A	:	Androecium
A	:	Adenine
ABA	:	Abscisic acid
ACTH	:	Adenocorticotrophic hormone
ATP	:	Adenosine triphosphate
Aa	:	Heterozygous dominant
AAAA	:	Autotetraploid
AABB	:	Allotetraploid
Å	:	Angstrom (= 0.0001 of a micron)
ADP	:	Adenosine diphosphate
AIDS	:	Acquired immuno deficiency syndrome
ANS	:	Autonomous nervous system
AMP	:	Adenosine monophosphate
1 Atmosphere	:	76.00 cm of Hg = 1.01 10^5 Pa.
ANS	:	Autonomic Nervous System
arg	:	Arginine
ACT	:	Acoustic test facility
ADH	:	Antidiuretic hormone
5 Bro	:	5 Bromo uracil
Br	:	Bracteate flower
Φ	:	Bacteriophage
BOD	:	Biochemical oxygen demand
BMR	:	Basal metabolic rate
C	:	Corolla
C	:	Cytosine
C_2	:	Plants showing photorespiration
CDP	:	Cytosine diphosphate
CTP	:	Cytosine triphosphate
CT	:	Calcitonin hormone
CoQ	:	Coenzyme Q
Cyt	:	Cytochrome
Cp	:	Compare
CMP	:	Cytosine monophosphate
CVA	:	Cerebrovascular accident
C_4	:	Plants with Hatch and Slack cycle
CoA	:	Coenzyme A
C	:	Cytosine
C_3	:	Calvin cycle plants
COD	:	Chemical oxygen demand
CIFRI	:	Central inland fisheries research institute
DNP	:	Deoxyribo nucleoproteins
DLC	:	Differential leucocyte count

DDT	:	Dichlorophenyl trichloroethane
DPD	:	Diffusion pressure deficit
DPT	:	Diphtheria, Pertussis, Tetanus vaccine
DNA	:	Deoxyribose nucleic acid
DPN	:	Diphosphopyridine nucleotide (Same as NAD)
EPR	:	Electro paramagnetic resonance
ECG	:	Electrocardiograph
EDTA	:	Ethylene diamine tetra acetic acid
EEG	:	Electro encephalograph
Ebr	:	Ebracteate
EMP	:	Embden Meyerhof Parnas pathway
ESR	:	Electron spin resonance
Epi	:	Presence of epicalyx
ETS	:	Energy transfer system
ER	:	Endoplasmic reticulum
EM	:	Electron microscope
FSH	:	Follicle stimulating hormone
FAD	:	Flavin adenine dinucleotide
FMN	:	Flavin mono nucleotide
F_2	:	Second filial generation
$FADH_2$	:	Flavin adenine dinucleotide (reduced)
F_1 particle	:	Oxysomes in mitochondria
F_1	:	First filial generation
GMP	:	Guanosine monophosphate
GA	:	Gibberellic acid
G	:	Guanine
GH	:	Growth hormone
GTH	:	Gonadotrophic hormone
HCLV-III	:	Human cell leukaemia virus III
HIV	:	Human immuno deficiency virus
ICSH	:	Interstitial cells stimulating hormone
IAA	:	Indole-3-acetic acid
ICRAF	:	International council for research in Agroforest
IU	:	International unit
IMP	:	Inosine monophosphate
IVI	:	Intravenous injection
IBA	:	Indole-3-butyric acid
1 light year	:	9.46 10^{15} km
LSD	:	Lysergic acid dimethylamide
LH	:	Luteinising hormone
mRNA	:	Messenger Ribose Nucleic Acid
1 microgram	:	10^6 gm
1 microlitre (ml)	:	10^6 litre
MET	:	Magneto-encephlography
MSH	:	Melanocyte stimulating hormone
NMRI	:	Nuclear magnetic resonance imaging
NAD	:	Nicotinamide adenine dinucleotide
$NADH_2$	:	Nicotinamide adenine dinucleotide (reduced)
NAA	:	Naphthalene acetic acid
n	:	Nanometre
PEPA	:	Phosphoenol pyruvic acid
Pstd	:	Pistillode
PAN	:	Peroxyacyl nitrate
PEM	:	Protein energy malnutrition
PPi	:	Inorganic pyrophosphate
P	:	Perianth
PQ	:	Plastoquinone
PGA	:	Phosphoglyceric acid
PKU	:	Phenylketonuria
PS-I	:	Pigment system I
PS-II	:	Pigment system II
PIH	:	Protein inhibiting hormone
PPLO	:	Pleuro pneumonia-like organisms
RH	:	Releasing hormone
RG	:	Regulator gene
RuBP (RuDP)	:	Ribulose biphosphate
RER	:	Rough endoplasmic reticulum
RMP	:	Ribulose monophosphate
RNA	:	Ribose nucleic acid
RQ	:	Respiratory quotient
SER	:	Smooth endoplasmic reticulum
S	:	Svedberg unit
SCID	:	Severe combined immunodeficiency syndrome
SQUID	:	Superconducting quantum interference device
TP	:	Turgor pressure
tRNA	:	Transfer ribose nucleic acid
TLC	:	Total leucocyte count
T	:	Thymine
TPN	:	Triphosphopyridine nucleotide
TTP	:	Thymidine triphosphate
TSH	:	Thyroid stimulating hormone
TPP	:	Thymine pyrophosphate
TCA	:	Tricarboxylic acid cycle
UMP	:	Uridine monophosphate
UAG	:	Nonsense codon
U	:	Uracil
UTP	:	Uridine triphosphate
UV	:	Ultraviolet
ABP	:	Androgen binding protein
ARF	:	Acute renal failure
WBC	:	White blood corpuscles

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UNIT I

DIVERSITY OF LIVING ORGANISMS

- THE LIVING WORLD
- BIOLOGICAL CLASSIFICATION
- PLANT KINGDOM
- ANIMAL KINGDOM

CHAPTER 1

THE LIVING WORLD

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The earth is a home of about 8.7 million species of living beings. Living beings are found in varied habitats like mountains, oceans, forests, lakes, deserts and even hot water springs. These show both intra as well as interspecific ecological conflicts as well as cooperative interactions. The life as seen and felt today can hardly be defined or described. Life appeared on earth millions of years ago.

WHAT IS LIVING?

The living possess certain characteristics like :

1. Shape and size. Living beings have a definite shape and size, which get modified to some extent when growth occurs. Living beings have been called as **morphous** (with definite shape) while non-living objects are called as **amorphous** (no definite shape).

2. Growth. Growth is characterised by increase in mass and increase in number of individuals. The growth of a living organism is an internal and biological process controlled by protoplasm. Non-living structures increase their size mostly due to external factors **(accretion).** Organisms grow due to cell division. Plants, for growth show cell division through out the life. Animals show growth in up to certain age. Growth in living organisms is called **intussusceptional growth** and is the end result of metabolism going on in the bodies of all living organisms.

3. Reproduction. All living organisms have power of reproduction. It is the capability to produce young ones of similar kind. Organisms may reproduce by asexual or sexual methods. Asexual reproduction **(budding)** is observed in yeast, *Hydra*. **Regeneration** is present in *Planaria* (flat worm). Fragmentation is very common in many fungi, filamentous algae and protonema of mosses. The young ones grow become adult, which again produce offsprings in their turn. Thus the continuation and multiplication of every individual is maintained to avoid extinction due to their deaths. In one-celled organisms, growth and reproduction are synchronous e.g., *Amoeba*. Reproduction is not an exclusive characteristic of living as some organisms do not reproduce e.g., worker bees, mules, etc. **Non-living objects** do not increase their number by reproducing themselves.

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Table 1. Differences between Anabolism and Catabolism.

Characters	Anabolism	Catabolism
1. Definition	It is sum total of constructive processes.	It is sum total of destructive processes.
2. Energy change	Kinetic energy is converted into potential energy.	Potential energy is converted into kinetic energy.
3. Substances	Complex substances are formed from simpler ones.	Simpler substances are formed from complex ones.
4. Energy	Stored.	Released.
5. Processes	Required for growth, maintenance.	Required for performance of activities.

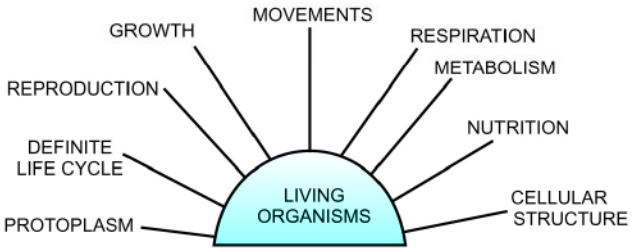

Fig. 1. Characteristics of living organisms.

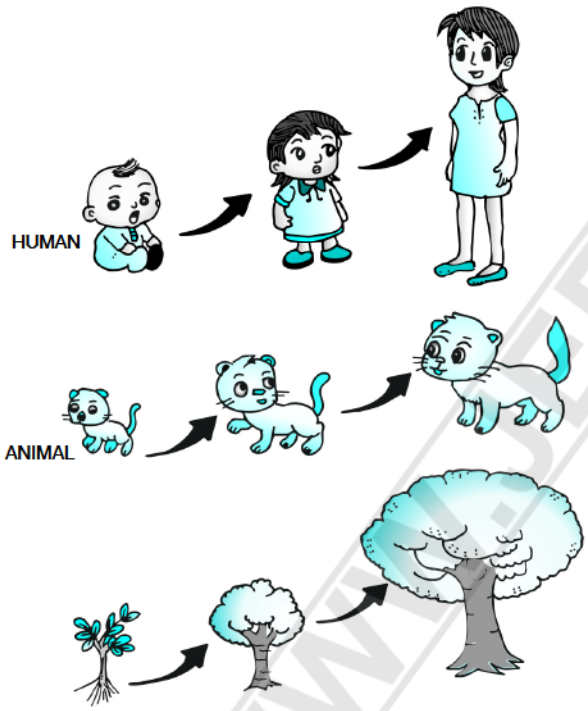

Fig. 2. The size of living things changes as time goes by.

4. Metabolism. The protoplasm of a living organism is formed of different types of biomolecules which are continuously consumed or synthesized or interchanged by various types of chemical reactions, collectively called metabolic reactions or **metabolism**. Metabolic reactions may be **anabolic** or **catabolic.** Feeding, digestion and assimilation together constitute **nutrition.** Nutrition in an organism results in the production of more protoplasm and also in addition in weight of the body. It is called **anabolism** or **constructive metabolism.** Anabolism is a synthetic phase, which results in the formation of complex substances from simpler ones e.g. photosynthesis. **Catabolism** is a process of breakdown. Here complex substances are broken down into simpler ones e.g. respiration. Respiration involves taking of oxygen and production of carbon dioxide along with energy. This energy is used for carrying on various life activities. In the living organisms, metabolic reactions are also possible *in vitro* (i.e., cell-free system). Metabolism is a **peculiar characteristic** of life as no non-living object shows metabolism.

5. Cellular organisation. All living organisms are made up of **cells.** Numerous organelles of cell carry out variety of co-ordinated functions. Cellular organisation is the **defining characteristic** of the living organisms as no non-living structure has cellular nature.

6. Consciousness. Consciousness is ability of organism to sense various environmental (i.e., external) as well as internal stimuli and to respond to them to keep a balanced condition called **homeostasis.** Consciousness is a defining property of all the living organisms. Human being is the only organism, who is aware of himself i.e. self-consciousness. The **reaction** or **response** by living organisms to the changes in environment is called **sensitivity.**

7. Definite life cycle. The living beings show a systematic and orderly cycle in their life time starting from birth to death. Life cycle involves birth, growth, reproduction, senescence and death.

8. Movements. Animals are able to move freely from one place to another. Most of the plants do not exhibit clear movements. They remain anchored to the soil. They show movements in the form of variations or curvature.

9. Protoplasm. All living beings show vital activities of cell due to presence of protoplasm. Protoplasm has been called as **physical basis of life.**

10. Self regulation. A control system works in every organism which helps in regulation of body functioning like growth, excretion, development, reproduction and other metabolic activities. Most of

animals have nervous and hormonal systems for self-regulation, while the higher plants have only hormonal system for it.

11. Co-ordination. All the parts of an organism co-ordinate and co-operate with one another for better functioning of the body.

12. Genetic material. All living beings bear genetic or hereditary material in the form of DNA. It is responsible for expression of traits in organisms.

13. Adaptations. Adaptations are the variations which help the living beings to modify themselves and show perfect harmony with changed surroundings.

14. Morphogenesis. Morphogenesis is the development of germinal layers, organs and other parts of an organism. During this process, zygote forms blastula, blastula changes into gastrula and gastrula forms a miniature organism.

Activity-1

Welcome to the exciting and amazing world of living things. Go outside and look around you. Look at the sky, the soil, trees, plants, people, animals. Nature is all around you if you have the eyes to see it. Count how many living things you can see.

What is it that makes living things different from things that are not alive?

Briefly, some characters of living beings are :

1. Living things are highly ordered.
2. Living things are organized into units called **cells.**
3. Living things **use energy** from their environment.
4. Living organisms **respond to stimuli.**
5. Living organisms always show **metabolism.**
6. Living things **reproduce** themselves.
7. Living things contain **genetic information.**

DIVERSITY IN THE LIVING WORLD

The group comprising the plants and animals is so large and there are so many variations that previously it was almost impossible to arrange the heterogeneous collection in systematic order. All living organisms vary considerably in their form structure and mode of life. The diversity of minerals number in thousands, but there are millions of living species. There are more than **1.7 to 1.8 million species** described and several more to be discovered yet. During the 3.5 billion years of life on earth, many living species have become extinct and still many have evolved. Out of extinct species some have been identified with the help of fossils.

The term **biological diversity** or **biodiversity** refers to the variety of life forms and habitats found in a defined area. UNEP (1992) defines it "**as the variety and variability of all animals, plants and micro-organisms and the ecological complexes of which they are a part**". The term biodiversity was coined by **W.G. Rosen (1985).** Diversity characterizes most living organisms, the our earth supports 8.7 million species of plants and animals which have been the result of 3 billion years of evolution involving mutation, recombination and natural selection. Biodiversity is an umbrella term covering diversity at genetic, species and ecosystem level. The convention on Biological Diversity defines biodiversity as " **The variability among living organisms form all sources including, interalia terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems.**" In short it refers to the whole variety of life on earth.' **Biodiversity represents the totality of genes, species and ecosystems of a region.**

Table 2. Distribution of species of some major groups of flora and fauna in India.

Group-wise species Distribution			
Plants	**Number**	**Animals**	**Number**
1. Bacteria	850	8. Lower groups	9979
2. Fungi	23,000	9. Mollusca	5042
3. Algae	2500	10. Arthropoda	57,525
4. Bryophytes	2564	11. Pisces (Fishes)	2546
		12. Amphibia	428
5. Pteridophytes	1022	13. Reptiles	1228
6. Gymnosperms	64	14. Birds	204
7. Angiosperms	15,000	15. Mammals	372

SYSTEMATICS TAXONOMY

It is the functional science which deals with identification, nomenclature and classification of different kinds of organisms all over the world. The word taxonomy is derived from two Greek words *(taxis + nomos)* meaning classification and law. Term taxonomy was coined by **de Candolle.**

All living organisms can be classified into different **taxa.** This process of classification is **taxonomy.**

Taxonomy can also be defined as **the study of the classification of plants and animals and their evolutionary relationship**.

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Phylogeny is the evolutionary history or lineage of one or more groups of organisms. It is based on the study of fossils, comparative anatomy and other branches of study like genetics, developmental biology, biochemistry, physiology, etc.

Basics of taxonomy are :

(i) Characterization

(ii) Identification

(iii) Classification

(iv) Nomenclature

The present method of classifying organisms was originated by **Carolous Linnaeus**, a Swedish naturalist in eighteenth century. This linnean system of classification has since become greatly elaborated and is now in universal use. It is mainly based on the fact organisms with similar body construction belong to same classification group. In this classification evolutionary inference is also made.

Closely related species are grouped together in the next higher unit of classification; the **genus** (pleural—genera). The scientific names of plants and animals consist of two words, the genus and the species, given in Latin. This system of naming organisms, called the **binomial system**, was first used by **Linnaeus**. This type of classification was based on their structural similarities; but these similarities are due to different **gene pools**. So, the modern classification of plants and animals is linked with evolutionary relationships and resembles in many respects to the one given by **Linnaeus**.

Present day complex organisms have appeared from simpler ones during geological time is further confirmed by various fossils studies.

For animals and some plants, there is an extensive **fossil record** that gives the clear-cut idea of organic evolution and also provides details of **phylogeny**. The **fossil** (L. *fossilium* — something dug up) tells us not only about bones, shells, teeth and other hard parts of an animal or plant body which have been preserved, but **to any impression or traces left by some previous organism**. The science of **palaeontology** deals with finding, cataloguing and interpreting the abundant and direct evidence of life in earlier times. Representing the remains of formerly living individuals, fossils provide the most direct evidence of the kinds of organism in existence at various earlier times.

Fossils found in earth's oldest fossil bearing geological formations are the simplest. They resemble present day **bacteria** and **blue-green algae** (photosynthetic cyanobacteria).

Identification should not be confused with classification. **Identification means determination of correct place of an organism in a previously established plan of classification.** Classification is just like grouping a collection of books in a large library, keeping in mind the author and subject of books for the first time. To find a correct place to locate a new title is equal to identification.

Speciation. The unit of classification in both plants and animals is **species.** It is difficult to give a definition of this term which can be applied uniformly throughout the animal and plant kingdoms, but a **species** may be defined as a **population of individuals with similar structural and functional characteristics, which have common ancestry and in nature breed only with each other.** So, the basic unit of classification is the species (plural species). It is like in a library where the book titles and in a dictionary words act as basic units.

Systematics (Greek—*systema*). It is the scientific study of kinds and diversity of organisms and of any or all relationships among them.

Or

It may be defined as a discipline which deals the kinds and diversity of all organisms and their existing relationships amongst themselves.

Or

It is a study of classification of different organisms and relationships amongst them.

It is based on the following fundamentals :

(i) Taxonomy. It is a functional science which deals with identification, nomenclature and classification of different kinds of organisms all over the world. So, taxonomy is the theory and practice of identifying and classifying plants and animals. The word taxonomy is derived from two Greek words (*taxis* + *nomos*) meaning classification and law.

(ii) Classification. It is the system of arrangement of organisms into groups showing relationship. In this, the various plants and animals are kept in different categories based on particular characters.

In other words, it is the placing of an organism or a group of organisms in categories according to a particular system and in conformity with a nomenclature system.

(iii) Identification. It is to determine the exact place or position of an organism in the set plan of classification.

(iv) Nomenclature. The process of giving scientific names to plants and animals is called nomenclature.

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DID YOU KNOW?

- In **Artificial Systems of Classification** in which habit, habitat and a few morphological characters are used for grouping or organisms. It was proposed by **Linnaeus.**
- In **Natural Systems of Classification**, organisms are arranged to their natural affinities through the use of all important permanent characteristics particularly structural, cytological, reproductive and biochemical. It was proposed by **John Ray.**
- In **Phylogenetic Systems of Classification**, evolutionary relationships of organisms are brought out. It was proposed by **Engler and Prantl.**
- **Numerical taxonomy (Phenetics)** is also called **Adansonian taxonomy** and is based on the number of shared characters.

Genus is a group of species which resemble with each other in their structural and functional characters. Species represents a group of individuals having morphological characters in common and which reproduce among themselves to produce their progeny. The name of Pipal is *Ficus religiosa.* The word *Ficus* is genus and *religiosa* is species.

(v) Key. A key provides a convenient way for easy identification of an organism by applying diagnostic or distinguishing characters.

Now-a-days systematics has gained a unique and important position in Biological Sciences. Today it is being studied with other branches of Biology such as in the form of 'Cytotaxonomy', 'Ecological systematics', 'Molecular systematics', 'Biosystematics' and 'Numerical taxonomy'.

Functions of biological classification or taxonomy are:

1. It recognises and describes the basic taxonomic units or species.

2. It tells a possible way of grouping these units on the basis of their resemblances and relationships.

As the species have a common ancestor, all the members of a species have same **hereditary or genetic material.**

CLASSIFICATION GUIDELINES

Following are the principles and criteria for a taxonomist or systematist while classifying an organism.

Classification is a mode of arranging organisms or group of organisms into categories according to a systematic plan as per nomenclature system.

While examining the various characteristics, he should keep in mind the various similarities and differences in the following fields :

(a) Morphology (external characters)
(b) Anatomy (internal structure)
(c) Cytology (cell structure)
(d) Physiology (life processes)
(e) Ontogeny (development)
(f) Reproduction
(g) Behaviour
(h) Biochemistry

1. Classical taxonomy. The branch of taxonomy which believes that individuals are mere expression of same type in terms of morphological variations is called **classical taxonomy.** Classical taxonomy originated with Plato. Support was provided by Aristotle (Father of Zoology), Theophrastus (Father of Botany), Linnaeus (Father of Taxonomy) and others.

Interesting features of classical taxonomy are :

(i) This type of classification is based on few characters.
(ii) Species are delimited on the basis of morphological characters.
(iii) Species are said to be immutable or static.
(iv) Species are considered to be most important for study. Sub-units of species are not considered important for taxonomical studies.
(v) Few individuals of a species or their preserved specimens are used for study. This is called **topological concept.**

2. Cytotaxonomy. Due to phylogenetic studies, it has been established that species is a **dynamic** and **ever changing** entity. This view has been supported by studies on cell and genetics **(cytotaxonomy).** Species based on pure **morphological** characters are being gradually changed by keeping in mind the characters drawn from other branches of biology.

3. Chemotaxonomy. Chemotaxonomy is also being used to study the plant relationships. This branch tells us the taxonomic relationships based on the distribution of certain characteristic chemical constituents.

4. Modern taxonomy/New systematics. In modern taxonomy, species has been considered as product of evolution. Here evidences are collected from various fields like cytology, genetics, morphology, anatomy, physiology, biochemistry etc. **Julian Huxley** (1940) initiated this view. New systematics is based on :

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(i) Many individuals are studied to known the variations.

(ii) Delimitation of species is done on the basis of all types of biological characters (**biological delimitation**).

(iii) Speices have been considered as **dynamic.**

(iv) Sub-species, species, varieties, races, populations, all are studied. That is why modern taxonomy is also known as **population systematics**.

BINOMIAL NOMENCLATURE

Nomenclature deals with the correct naming. An organism must be known by the same scientific name throughout the world. Therefore, standardization of organisms/plants names is very essential for advancement of biological sciences.

Nomenclature means system of naming of plants, animals and other objects. In every nation different names are being used for plants and animals in their own language.

The present system of binomial nomenclature dates back from the time of **Linnaeus,** who discussed it in 1753 in **Species Plantarum.** The method was so convenient to the biologists all over the world that it was universally accepted. **Candolle** (1813) in his **'Theorie elementaire dela botanique'** gave the significant works on nomenclature after Linnaeus :

Advantages of common (vernacular) names

1. Vernacular names are brief e.g. Mirch (Chilli), Onion, Gobhi (Cabbage) etc.

2. Usually they represent a particular interesting character of organism e.g. chirya (sparrow)—due to chirping, dodhak—due to production of milky latex.

3. Local people get familiar with common names from childhood.

4. They are usually easy to pronounce.

5. By common names, natives are able to identify them easily.

Disadvantages of common (vernacular) names

1. All the animals and plants have not been named.

2. Sometimes one animal or plant is given different names in other parts of the world. Bird 'gauraiya' in India is known by the name house sparrow in England;

Pordal in Spain; Musch in Holland; Sezune in Japan. Similarly, bird partridge, in India, is also known as Quat or Bobwhite.

3. A common name may include several organisms *e.g.* 'Titlee' includes butterflies as well as moth.

4. A common names are misleading *e.g.* Cuttle fish, Jelly fish and Starfish are not fishes. Sunflower capitulum is not a flower but it is an inflorescence.

5. Plants and animals are known with different names in different states and cities of same country *e.g.* a plant is called China rose in English, Gurhal in Hindi, Jaba in Bengali and so on. Onion in English is *pyaz* in Hindi and Bengali, *vengayam* in Tamil and *irrulli* in Kannada and so on.

6. No scientific basis lies for selecting a common name.

Binomial nomenclature of plants and animals

According to this system every name comprises of two words a substantive **'Genus'** and an adjective **'Species'.** Genus is common to all the species. The name of the species is based on some fixed and definite characters. Most of generic names are Latin and Greek words which usually indicate some property possessed by plants or animals. Sometimes generic names are also given on the names of distinguished Botanist and Zoologist *e.g.* Liverwort *Sewardellia* (after Prof. Seward) or lichen *Choudaria* (Dr. H.P. Chaudhry). Specific names follow the genus and are written in small letters except

Table 3. Differences between Classical taxonomy and Modern taxonomy.

Characters	Classical taxonomy	Modern taxonomy
1. **Number of Individuals**	One or few individuals are selected for study to describe a species.	Large number of individuals are selected to describe a species
2. **Characters studied**	Study is based on morphological characters only.	Study is based on many fields.
3. **Species type**	Static or fixed of evolution.	Dynamic and everchanging entity.
4. **Type of classification**	Responsible for appearance of artificial system of classification.	Deals with natural and phylogenetic systems of classification.

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when they are indicative of important personages *e.g. Pinus roxburghi* (after Prof. Roxburgh). The name of the author is described after the name of species *e.g. Solanum tuberosum* Linn. Obviously Linn. here refers to Linnaeus. Other examples are *Homo sapiens* Linn., *Aloe barbadensis* Mill. Sometimes specific name can be given after a country or locality *e.g. Rosa indica, Rumex nepalensis.*

Carolus Linnaeus (1707-1778)

Carolus Linnaeus (1707-1778)

He is known as **"Father of modern botany".** He is the founder of modern concept of classification. He was a Swedish naturalist who became interested in the study of natural history since his childhood. While a student at university of Uppsala, he published his first paper on sexuality of plants (1729) under the guidance of Dr. Rudbeck. Later in 1730, he enumerated plants of Uppsala Botanical Garden in **Hortus uplandicus.** In his new edition of Hortus uplandicus (1732), he classified plants on the basis of his so called sexual system. He received his M.D. degree from university of Harderwijk in 1735. His book **Systema Naturae** appeared in 1735 providing the foundation for the classification of plants, animals and minerals. In 1737, he published **Hortus Cliffortianus** based on the plants present in the Garden of George Clifford. His **Genera Plantarum** and **Classes Plantarum** appeared in 1737 and 1738 respectively. He published the revised version of his earlier classification of plants, given in Systema Naturae (1735) and Classes Plantarum (1738), in his book **Philosophia Botanica** in 1751. While working as a Professor of Botany and medicine at university of Uppsala, he published his **Species Plantarum** in 1753 describing 7300 species of about 1000 genera and arranging them on the basis of his sexual system of classification. He used the binomial system of nomenclature. Species Plantarum was revised several times and remained the most significant system of classification until the beginning of nineteenth century.

International Code of Botanical and Zoological Nomenclature

In 1948, International Congress of Zoology and in 1950 International Botanical Congress set the various rules for Binomial nomenclature. To provide for uniformity and to avoid confusions, 12th International Congress at Leningrad in 1975, laid down certain general principles of nomenclature which were published in 1978 in the form of **International Code of Botanical Nomenclature** (ICBN) and **International Code of Zoological Nomenclature** (ICZN). This has been done, keeping in mind to put the nomenclature of the past in order. It also provides right guidelines for future nomenclature. **Lanjouw** gave the following principles for classifying the plants :

1. Difficult and long generic names should be avoided.

2. Species should not be identified due to its size.

3. Colour should not be criterion for difference.

4. Species should have a smaller name.

5. The name of the author should be written after the specific name in Roman type and without comma between them.

6. The name should be easy to pronounce.

7. The name should refer to some important character of the plant.

8. The name should not contain less than three and more than twelve letters.

Advantages of the system

1. The biological names are the same all over the world.

2. They are uniformly binomial.

3. They are definite and accepted universally.

4. They are descriptive.

5. They indicate the general relationship.

6. Biological names have been derived mostly from Latin or Greek language. Both of these are dead languages. Hence, there is no chance of change in meaning of their words.

7. An incorrect name can be easily set right.

8. All newly discovered plants and animals can be named and described easily.

TAXONOMIC CATEGORIES

Classification is placing of an organism or group of organisms in **categories** according to a particular system and in conformity with a nomenclature system.

Category. Plants and animals are ranked in an arrangement of known categories. Such as kingdom, phylum (for animals), division (for plants), class, order, genus and species. The highest category in animals is phylum and the lowest is the species.

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ADDITIONAL USEFUL INFORMATIONS ABOUT BINOMIAL NOMENCLATURE FOR COMPETITIVE EXAMINATIONS

- ***Guiding principles of nomenclature***
  - (i) ***Correct name.*** *It should be in accordance with rules.*
  - (ii) ***Latin.*** *Scientific names are treated as Latin, regardless of their derivation.*
  - (iii) ***Priority.*** *Nomenclature of taxonomic groups is based upon priority of publication.*
  - (iv) ***Type.*** *The application of names is determined by nomenclature types.*
  - (v) ***Retroactive.*** *Nomenclature rules are retroactive.*
  - (vi) ***Independent.*** *Botanical nomenclature is independent of zoological nomenclature.*
  - (vii) ***Publication.*** *Biological names should be effectively and validly published.*
- *In 1821,* ***Stendel*** *in his book Nomenclator botanicus gave a list of Latin names of all flowering plants at that time together with synonyme.*
- *International Code for Nomenclature is divided into three parts i.e.*
  (i) Principles (ii) Rules and recommendations (iii) Provisions.
- *Usually very long names have been avoided but few examples of very long names are :*
  (i) Swartschewskiechinogammarus
  (ii) Toxophthalmoechenogammarus
- *After the work of Linnaeus, another significant publication was that of* ***Augustin de Candolle*** *in Theory Elemantaire de la botanique.*

The classification is not a single step process. In it hierarchy of many steps are involved where each step represents a **rank or category.** Because category is the part of overall taxonomic arrangement, it is called **taxonomic category** and all categories together form **taxonomic hierarchy.** Each category basically represents a **rank** and usually called as **taxon.**

Aims of International Code of Botanical Nomenclature are avoidance and rejection of the names which may cause confusion, to check useless creation of names, stable method for naming the taxonomic groups and to keep the old nomenclature in proper order to be used for future.

The principles are being discussed below :

1. Ranks or taxa. Taxon is a taxonomic group of plants of any rank *e.g.* The genus *Thespesia* Sol. ex Correa is a taxon. The family *Malvaceae* Juss. is a taxon. The rules of nomenclature prescribe the categories for plant classification. These categories (taxa) constitute the units of classification. A taxon with common ancestral species is called **monophyletic taxon or clade.** Many taxa bear organisms evolved from many sources but not common ancestor are called **polyphyletic or grade** e.g. taxon mammalia. The basic unit of classification is species. All the units are arranged in descending order of magnitude. This arrangement is fixed and shown below:

Kingdom
Division/Phylum
Sub-division/Sub-Phylum
Class
Sub-class
Order
Sub-order
Family
Sub-family
Tribe
Sub-tribe
Genus
Sub-genus
Section
Species

Categories below the rank of species are :

Sub-species
Varieties
Sub-varieties
Forma
Clone

Principal ranks of taxa (with example) are given below :

Rank	Example
Kingdom	Plantae
Division	Magnoliophyta
Class	Magnolitae (Dicots)
Order	Malvales
Family	Malvaceae
Genus	*Thespesia* Sol. ex Correa
Species	*populnea*

2. Forms of scientific names. Names of orders are taken from that of one of their principal families ending in **– ales.** Sub-orders are denoted in a similar way, with the ending **- ineae**. Name of families and sub-families are taken from the name of an existing or former genus ending in **- aceae** and **- oideae,** respectively. Name of genus may be taken

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from any source and may be composed in any arbitrary manner. Names of species are binary combinations consisting of the name of genus followed by a single specific epithet.

Example :	**Order**	—	Rosales
	Family	—	Rosaceae
	Genus	—	*Rosa*
	Species	—	*indica*

3. Various taxonomic categories are :

Species. Species is the most important category in taxonomic hierarchy. It is the basic unit of evolution. **It is a group of individuals in plants as well as animals which resemble closely in structure as well as in functions.** It is very important unit, not only for taxonomists, but also for working in allied fields of Biology as well.

General characters of species

1. They show similar morphological characters.

2. They can interbreed freely and truly in nature. They produce fertile offsprings.

3. Ordinarily, they cannot breed with other species.

In *Mangifera indica* (Mango), *Solanum tuberosum* (Potato) and *Panthera leo* (Lion), *indica*, *tuberosum* and *leo* represent the specific epithet. First words like *Mangifera*, *Solanum* and *Panthera* are genera and represent another **taxon** *or* **category.** Each genus may bear one or more specific epithet.

Genus (plural — genera)

It informs the taxonomic category higher than species. It is a group of closely related species *e.g.* Dog, Jackal and Wolf are placed in the same genus *Canis*, because they are closely related to each other but belong to different species. Similarly potato, brinjal etc. are placed in same genus *Solanum* but belong to different species e.g. *tuberosum* and *melongena* respectively. Groups of common characters in species of a genus are called **correlated characters.** Sometimes a genus may be made up of only one species as in man the genus is *Homo.*

Family

A number of genera having several common characters forms a family *e.g. Solanum, Petunia* and *Datura* have some characters in common. That is why they have been placed in the same family *Solanaceae.* The genus *Vulpus* (of foxes) shows few characters common with *Canis*. Thus, both the genera are placed in family Canidae.

Order

A number of families having common characters are placed in an order. Dogs belong to family Canidae. The cat, tiger etc. belong to family Felidae. The bears are included in family Ursidae. Because dogs, cats and bears are carnivorous their families are included under order Carnivora.

Plant families like Convolvulaceae and Solanaceae are included in order **Polimoniales** mainly based on the floral characters. Animal order **Carnivora** includes families like Felidae and Canidae.

Class

The class is a basic category. Similar orders are placed together in a class. Class Mammalia includes orders like Carnivora, Chiroptera, Rodentia and Primates. They have few characters in common *i.e.* the presence of mammary glands and hairs.

Phylum

Many classes with some common characters are included in a **Phylum.** Phylum Chordata included classes like Pisces, Amphibia, Reptilia, Aves and Mammalia because all have common characters like presence of notochord, dorsal hollow nervous system and pharynx perforated by gill slits.

Kingdom

It is the highest category of taxonomic studies. All animals are included in animal kingdom and all plants are included in plant kingdom.

Hierarchy

It is a system of arrangement or a framework for classification in which various taxonomic categories

Table 4. Differences between Species and Taxon.

Characters	Species	Taxon
1. **Category**	It shows basic taxonomy category.	It shows any level of taxonomic category.
2. **Representation**	It is a rank and represents an abstract term.	It represents a group of concrete biological objects.
3. **Phyletic**	Monophyletic	Monophyletic or polyphyletic.

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are placed in order of logical sequence. The variations noticed in the living organisms are not uniform. It can be arranged in various groups of different ranks.

Hierarchy literally means 'a series of succession of different ranks'. So, the various species have been arranged into different **categories** and **taxa.**

Linnaeus was first to establish a definite hierarchy of taxonomic categories. The structure in which various taxonomic groups are assigned to each of taxonomic category in hierarchy is known as **taxonomic structure.** The Linnean hierarchy consists of arrangement of categories in descending sequence. For plants and animals various seven categories are given below :

Kingdom	-	**Plantae**
Division	-	Embryophyta
Class	-	Dicotyledonae
Order	-	Sapindales
Family	-	Anacardiaceae
Genus	-	*Mangifera*
Species	-	*indica*

Animalia	-	**Kingdom**
Phylum	-	Chordata
Class	-	Mammalia
Order	-	Primata
Family	-	Hominidae
Genus	-	*Homo*
Species	-	*sapiens*

Major categories in descending order are phylum, class, order, family, genus and species. The sequence can be remembered by memorizing "**KEEP POT CLEAN OR FAMILY GETS SICK**". Such categories are known as **obligate categories.**

Mango and Man are known as *Mangifera indica* and *Homo sapiens* respectively in binomial system of nomenclature.

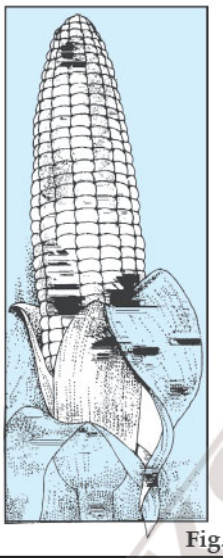

Fig. 3. Classification of Maize.

It is interesting to observe that the highest category has few characters in common for that particular category *e.g.* Genus *Panthera* (includes tiger, lion, leopard etc.) have large number of common characters as compared to class **Mammalia** (higher category). Few common characters of class mammalia are :

1. Presence of mammary glands.
2. Presence of hair on the body.
3. Presence of vertebral column and external ears.

Some categories are further divided into new ones by prefixing **super** or **sub** *e.g.* **subkingdom, subphylum, superclass, subclass.** The new category **tribe** has been added in between genus and sub-family. Animals are further identified by **subspecies.** They have trinomial names as *Gorilla gorilla gorilla.* They represent generic, specific and sub-specific names. Usually botanists do not give importance to sub-species but few cases do exist as *Brassica oleracea* var. *botrytis* (cauliflower). Here inspite of sub-species variety has been added.

Table 5. Examples of Species in each of Four Eukaryotic Kingdoms.

	Tiger	**Mango**	**House fly**	***Wheat***
Kingdom	Animalia	Plantae	Animalia	Plantae
Phylum or Division (Sub-phylum)	Chordata (Vertebrata)	Angiospermae	Arthropoda	Angiospermae
Class	Mammalia	Dicotyledonae	Insecta	Monocotyledonae
Order	Carnivora	Sapindales	Diptera	Poales
Family	Felidae	Anacardiaceae	Muscidae	Poaceae
Genus	*Panthera*	*Mangifera*	*Musca*	*Triticum*
Species	*tigris*	*indica*	*domestica*	*aestivum*

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Evolutionary relationships of the major phyla in five-kingdom system of classification.

R.H. Whittaker had chosen to base classification on three levels of organization the prokaryotic, eukaryotic unicellular, and multicellular-multinucleate and **three principal directions of evolution related to nutrition,** which on the multicellular-multinucleate level are expressed in the evolutionary divergences of the three higher kingdoms. The three higher kingdoms are polyphyletic in parallel fashions. Each includes a dominant evolutionary line to higher organisms as its major subkingdom, and minor subkingdoms which are independent experiments in multicellular or multinucleate organization in one of the three nutritive directions. In each case these minor subkingdoms are less widely successful than the principal subkingdom, represent somewhat lower and different organization from it, and may to some degree depart from the typical nutritive mode of the kingdom.

Fossil records always help in studying the phylogenetic relationships. Fossils of soft bodied organisms particularly monerans, protists, fungi, lower and non-woody plants are not available. In such cases evolutionary relationships are deducted by studying living existing organisms.

Category may bear sub or super-levels.

Key

A key provides a convenient way for easy identification of an organism by applying diagnostic or distinguishing characters *e.g.* to identify various members of family Liliaceae following diagnostic characters will be applicable to all the members (Onion, *Asparagus*, *Asphodelus* etc.).

1. Flowers trimerous, pentacyclic and hypogynous.

2. Calyx and corolla undifferentiated to form perianth.

3. Tepals 6, in two whorls, odd tepal of outer whorl anterior.

4. Stamens 6, antiphyllous and epiphyllous.

5. Tricarpellary, axile placentation.

NEED AND SCOPE OF TAXONOMY

The **multiple role of systematics or utility** of systematics can be described as below :

1. Diversity. It provides us a knowledge of diversity of plants and animals on the earth. Systematics at one time was considered to be dry and boring subject with little relevance to human life. But now necessity of systematics is being felt in every field of biological sciences. It gives us most of the information permitting a reconstruction of phylogeny of life. It helps us in understanding the **evolution** which occurred among living organisms by knowing the distinction, affinities, habit and habitat.

2. Relationship with other branches. It provides necessary information required to **other branches** of **biology** *e.g.* a plant ecologist should be familiar with the names of the plants, their habit and habitat. No ecological survey can be carried out without the knowledge of systematics. For example, an ecologist working on soil conservation can select various plants and grasses for acting as soil binders. Same is true about other branches of biology also. As a result several inter-disciplinary subjects like cytotaxonomy, biosystematics etc. have developed.

3. Applied biology. It has a great role for **applied biology** also. The introduction of harmful plants can be checked.

4. Role in plant breeding. Exact identification of harmful **pests and their control** helps in plant protection. Many economically important plants are identified and selected for **breeding** work in the country to increase the yield and for the production of disease-resistant varieties.

5. Human health. Systematics is also useful in protection of **human health.** Exact identification of insects helps in controlling the epidemic disease. For example, many diseases like malaria, filaria, dengue fever, kala azar etc. are spread by different species of mosquitoes. It also helps in conserving the useful animals and plants.

6. Horticulture and floriculture. Knowledge of systematics is essential for **horticulture** and **floriculture** also. Several ornamentals have been introduced due to proper identification and nomenclature. Its knowledge is also required to study the natural resources of areas to know the land potential.

7. Preservation of wildlife. For preserving wildlife, identification of these organisms is necessary and systematics helps in this work.

8. Indicator organisms. Presence of certain organisms provide important information. For example, presence of protozoan *Colpidium* indicates the degree of pollution in water.

Systematics has its relevance in **fisheries** and for the study of **economically** and **medicinally important plants**. All pharmaceutical studies are based on the work of taxonomists. Taxonomists are being employed at various positions in museums, colleges, research institutes and in various public and private organizations. So, it has a wide scope as **profession** also.

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Table 6. Some common names and their category level.

Phylum	Class	Order	Family	Genus	Species
Flat worm	Fish	Bat, monkey	Tortoise	Wolf	Man
Round worm	Bird	Frog and toad	Cobra	Hooded cobra	Dog
	Insect	Turtle	Eagle	Crow	Horse
	(Millipede)	(Snake)	Crane		Domestic cat
	(Centipede)	Lizard	Woodpecker		Domestic cow
	Snail	Butterfly	Duck		Tiger
		Beetle	Elephant		Lion
		Spider	Bear		Indian elephant
		Scorpion	Deer		Indian peacock
		Earthworm	Ant		House sparrow
			Mosquito		House crow
Alga	Flowering plant	Mushroom	Grass	*Citrus*	Rice, wheat
(red, brown,	Moss	Yeast	Orchid	*Eucalyptus*	Potato
green)	Fern		Gourd	*Pinus*	Lemon
	Conifer		Bracket fungus		Orange
			Palm		Neem
					Banyan, Pipal
					Coconut
					Mango, Guava
					Edible button
					Mushroom
					Baker's yeast

PRACTICE PROBLEMS – SYSTEMATICS – BASIC CONCEPTS

1. What is cohort?
2. Enlist the categories of classification in their ascending order.
3. Distinguish between taxon or category.
4. Differentiate between species and taxon.
5. Describe hierarchical classification.

ANSWERS TO PRACTICE PROBLEMS

1. Cohort or order represents the unit of classification higher than family, which includes a group of closely related families.
2. **(a)** Species **(b)** Genus **(c)** Family **(d)** Cohort (order) **(e)** Class **(f)** Division or Phylum.
3.

Characters	Taxon	Category
Definition	Taxon represents to a group of organisms.	It refers to rank or status of a taxon.
Types	It is only of one type.	It is of two types *i.e.* major rank and minor rank.
Examples	Dicotyledons, monocotyledons, angiosperms	**(i) Major ranks** : Kingdom, Division, Class etc. **(ii) Minor ranks** : Genus, Species etc.

4. The species is a group of individuals that closely resemble each other either because they freely interbreed in nature or because they have descended from common ancestors. The taxon refers to concrete biological objects included in a category representing a rank.
5. Hierarchical classification is a system of arrangement for classification in which categories or ranks are placed in other of logical sequence. There are seven categories or ranks in the hierarchy. Any given species can be traced in descending order Kingdom, Phylum, Class, Order, Family, Genus and Species. Higher the category, the lesser will be the number of common characteristics of the organisms belonging to that category.

TAXONOMICAL AIDS

TOOLS FOR STUDY OF BIODIVERSITY

Organisms are to be identified on the basis of intensive laboratory and field studies. First of all plant specimens of different species are collected. They are identified and classified.

Specimens are preserved and stored for future studies. Some of the techniques followed are :

HERBARIUM

Herbarium. A herbarium is a collection of well-dried and nicely preserved plants which are correctly identified and arranged according to an approved system of classification. The plants are usually pressed and mounted on the sheets of paper known as **herbarium sheets**. The plants which are not suitable for pressing and mounting, like succulents, fruits and seeds of plants, cones etc., are either preserved in 2.5% formaline or FAA

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(Formaldehyde acetic alcohol) or dried and stored in large containers. These dried and preserved specimens in herbaria, are then available for reference in taxonomical, comparative and morphological studies whenever required. The work on the preservation of plants was started in sixteenth century when **Caesalpino** (about 1550) preserved the plant material he studied. Soon after, the importance of herbaria was realized and it became an essential feature of botanical work. Today, we find that most of the developed and developing countries of the world have their own herbaria comprising of valuable plant specimens.

Purpose of Herbarium

As the taxonomic field is becoming more and more wide, simple drawings, photographs and written descriptions are insufficient to provide the morphological and developmental details about the plants. So, it becomes necessary for the taxonomist to compare the newly collected plants with the specimens already collected and preserved in herbarium, for the required description. Mainly, the newly collected plants are identified on the basis of their morphological variations by comparing with the actual specimens in herbaria. Other purposes served by herbaria are :

(i) To serve as the reference material for modern taxonomical research.

(ii) To provide scientific information on plants to the people through exhibition, training courses etc.

(iii) To serve as national plant wealth repositories.

(iv) For the training of graduate students in botanical studies.

Making of Herbarium

1. Collection of plants. It is the first step in the direction of making a herbarium. The collection of plants must be done carefully and using a scientific mind. The plant material collected should be complete in such a way so that it can provide full information for its proper identification. As far as possible, the plants should possess all parts such as leaves, inflorescence, flowers, fruits and also the roots. The small sized (herbaceous) plant materials are collected with both underground and above ground portions while the large sized or woody plant materials may be represented by flowering and leafy twigs of proper length. The plants should be collected at every stage of growth and reproduction and from different habitats in different seasons. For this, the collector should go out on excursion frequently. The collection of diseased, infected or distorted plants should be avoided unless they are required. All the information regarding habit, habitat, locality, season, altitude, colour of flowers etc. should be recorded at the time of collection in a field note-book. At least 5-6 specimens per species should be collected and numbered corresponding to the information recorded in field note-book.

2. Pressing and drying. The collected plants are pressed immediately after collection before they get wilted. The plants are pressed in between the sheets of ordinary newspapers' foldings alternating with the sheets of blotting paper. Care should be taken while pressing so that the leaves are well spread. The sheet folders are then pressed in field press (size 30 × 45 cm). Drying of the specimens takes place by the loss of water content to blotting sheets. For this, the blotting sheets are to be changed frequently to avoid the decay and blackening of the plant material. Initial changes should be done at every 24 hrs or less duration for 3-4 days and after that 3-4 changes of longer duration are sufficient for the plants other than succulents. The latter require more frequent changes. Alternatively, the plants may be dried with the aid of artificial heat. In this case, the collected specimens are "sweated" in the field press for 24 hrs. They are then opened, examined and rearranged. Each sheet is then transferred to drying press. The drying press is then locked up and applied pressure which should be less than the pressure exerted on the plants when in the field press. The press is placed over the heat source. The press is tightened after 6 hrs and again after 12 hrs. It is also turned over so that the cool side faces the heat. The press is removed from heat source after 24 hrs, opened and all folders of dry specimens removed. The duration of heat drying varies with the intensity of heat source, from a minimum 12 hrs to 48 hrs. The heat source depends upon the choice and availability. Electricity is the most simplest, convenient and readily controlled source, while the use of incandescent bulbs, resistance coils etc. have been proved satisfactory.

DID YOU KNOW?

Some of the important herbaria of India are :

(i) Central National Herbarium (Kolkata). It is largest herbarium in India.
(ii) Herbarium of Forest Research Institute (Dehradun)
(iii) Madras Herbarium (Coimbatore)
(iv) Herbarium of NBRI (Lucknow)
(v) Regional herbarium of Shillong (Assam)
(vi) Regional herbarium of BSI (Pune)

Some important herbaria of other countries are :

(i) Herbarium Nationale de Historie Laboratories de Phanerogamie, Paris (Italy)
(ii) Royal Botanic Gardens Herbarium, Kew (Britain). It is largest herbarium in the world.
(iii) Cordon College Herbarium, Lahore (Pakistan)
(iv) Herbarium of Botanisches Institute de Universtate, Kiel (Germany)
(v) U.S. National Arboretum Herbarium, Washington (U.S.A.)

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3. Poisoning. Stored plant material may get attacked by insects and pests, thus, poisoning is needed for a good and intact specimen. It can be done by dipping the plant materials in 2% mercuric chloride solution when they are partially dehydrated. The specimens are again dried.

Poisoning can also be done by spraying 0.1% mercuric chloride solution on the specimens, when they are fully dried. Other chemicals used for prevention are naphthalene flakes, paradichloro benzene, DDT, carbon-disulphide gas etc.

4. Mounting and labelling. After drying, the plant materials are mounted on herbarium sheets of appropriate size (29 × 42 cm). The specimens are either glued or stitched or held by cellophane tape on the sheets. Only one specimen should be mounted on one herbarium sheet. While mounting, care should be taken so that the specimen is well spread, there is no overlapping and the specimen is preferably in the centre of the herbarium sheet.

Labelling of the specimen is done by entering the field information on the right hand side lower corner of the herbarium sheet. It bears the common name, genus, species, family, date of collection, habitat, locality, name of the collector and any other information regarding the morphology of the specimen, geographical or soil characteristics etc.

5. Storing of the herbarium sheets. The herbarium sheets mounted with specimens are then stored in wooden or steel almirahs. The steel almirahs are preferred over wooden cabinets because they protect the specimens from fire and insects. The herbarium sheets carrying specimens are kept arranged in a specific order according to a well-known and approved system of classification. Mostly, Bentham and Hooker's system of classification is followed for this purpose. Another system of classification given by Engler and Prantl is also followed. The arrangement of specimens according to a system of classification in herbaria is also termed as **filling** of the specimens.

BOTANICAL GARDENS

A botanical garden is a place where there is an assemblage of living plants maintained for botanical teaching and research purposes. Earlier, botanical gardens were started as physic gardens for the training of medical students and for the study of medicinal plants.

The origin of gardens can be traced back, long before the dawn of history when man grew plants in gardens which were of economic use to him. Ancient Indian History shows the cultivation of medicinal and food plants since 4000 to 2000 B.C. The plants were also grown for ornamental purposes around the temples and palaces. For this, the plants were being introduced from different places. The Romans, Chinese, Persians and Aztecs were very fond of gathering and growing plants for various purposes.

During the middle ages (about 600-1600 A.D.), no much attention was paid to gather or introduce the plants. However, the oldest botanic gardens, that of Pisa and those of Padua and Florence were established in Italy in 1543 and 1545 respectively, mainly for the study of medicinal and fossil plants. It were sixteenth and seventeenth century, when there was a great awakening in respect to the learning of numerous plants and growing them in gardens. This led to the development of great study institutes and their botanical gardens, very rapidly. There are more than 500 botanical gardens in various countries of the world.

In India, the first garden was originated in Bombay in 1830 by agricultural society. Then, in 1838, another botanical garden was established in Madras. Similarly, many gardens came into being afterwards e.g. at Ootacamund in Nilgiri hills; Nainital; Lloyd Botanic Gardens at Darjeeling etc.

IMPORTANT BOTANICAL GARDENS

Royal Botanic Garden, Kew, England

Presently, the garden extends over 250 acres of land. It was originally started in an area of 16 acres in 1759. William Aiton was appointed as its superintendent. It flourished with the efforts of Phillip Miller, Sir Aiton and Sir Joseph Banks until 1820. It was transferred from Crown of State in 1838. Sir W.J. Hooker took over as the director in 1841, who increased the number of plants and also the area of the garden. The important plants of the garden are, willows, lilacs, tulips, defodils, Japanese cedar, redwood, *Philadelphus*, oaks, sweet gum, Japanese cherries, dawn redwood, *Prunus*, crap apples, magnolias, maple, walnuts etc. There are various green houses like palm house, Alpine house, Water Lily house, Ferneries, Temperature house etc.

Indian Botanical Garden, Howrah

It is one of the first botanical gardens to be established in tropics. It was founded in 1787 by Robert Kyd for some economic reasons, but later developed

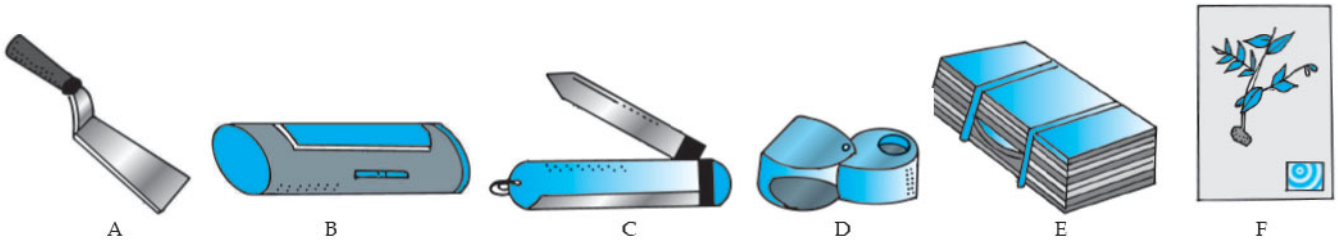

Fig. 4 . Essential equipment for field work.

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into a scientific institution. It covers an area of about 273 acres having a large collection of world's tropical plants. The garden was headed by William Roxburgh, father of Indian botany, from 1793 to 1813. He was followed by various well-known botanists including Wallich, Griffith, Anderson, George King, David Prain, D. Chatterjee and many others. George King is remembered as chief horticultural designer of the garden. He also started the publication of Annals of the Royal Botanic Garden, Calcutta in 1887 and later in 1890 initiated the Botanical Survey of India.

The garden possesses, among other features, a herbarium (Central National Herbarium). The garden and herbarium were handed over to the state government after independence, but later the control was given to Botanical Survey of India.

The other interesting features of the garden are :

The great Banyan tree. A specimen of *Ficus benghalensis* is about two centuries old covering an area of about 4 acres. Its main feature is that it has no main trunk but about 1000 pillar-like aerial roots which provide support to the canopy. It is about 100 feet in height and supposed to be the largest living creature of the world.

Palm houses. They are elegant metal structures covered with wire netting. A large number of pretty creepers are grown over the structures whose foliage provide the shade for the growth of rare palm, ferns and other shade-loving plants. One of the creeper is *Porana panniculata* with white flowers. Over forty species of palms are grown including the rare branching palm *Hyphaene thebaica*.

Nursery. It is one of the best nurseries of Asia, for the propagation of plants growing in the garden. It is maintained mainly with the purpose of replacement of plants, but young plants are also available for sale to general public and other institutions.

Some more interesting features of the garden are various interesting shrubs and trees including ornamental leguminous trees (*Saraca declinata, Saraca indica, Brownia, Amberstia* etc.), succulent plants from Euphorbiaceae and Cactaceae, a flower garden and the amazon lily (*Victoria amazonica*).

National Botanical Research Institute, Lucknow

The foundation of the garden was laid by Nawab Saadat Ali Khan (1789-1814) as a royal garden along the southern bank of river Gomti. It was improved later and named as Sikander bagh by Nawab Wajid Ali Shah. It existed as Government Horticultural Garden until 1948, when it was approved as National Botanic Garden. It was taken over by CSIR in 1953.

The main garden of the National Botanic Garden occupies an area of about 27 hectares enriched by a large collection of diverse plants including palms, ferns, medicinal plants, orchids, ornamentals and cacti alongwith a huge herbarium, library and green houses.

ZOOLOGICAL PARKS

Zoological Parks are those man-made places where animals are provided with conditions as similar as possible to their natural habitats. These are commonly called **zoos.**

Significance of zoological parks

1. These inform about mode of living, feeding habits and behaviour of wild animals.

2. Visits to zoological parks are source of excitation and enjoyment for the people, especially the children.

3. Their scientific purpose is to breed the threatened animals to increase their number to prevent their extinction. This is aimed to counter their decrease in number due to poaching and habitat destruction.

4. In the zoological parks, their common names and scientific names are displayed in front of their enclosures.

MUSEUMS AND THEIR SIGNIFICANCE

Museums are those institutions which have collection of preserved plants and animals for study and reference. All colleges maintain museums in the Botany and Zoology Departments. Animal specimens like worms, insects, fishes, reptiles etc. are kept in jars in suitable preservatives like 3-7 % formaline or FAA. Insects after drying can be mounted in boxes. Larger animals can be stuffed and can be kept in skeleton forms.

Significance of Museums

1. In these, the specimens are **preserved for longer duration** by placing them in chemical preservatives.

2. Here the plants like algae, fungi, mosses and ferns, parts of gymnosperms are preserved as these cannot be maintained in the botanical gardens.

3. The preserved plants inform about the **habitat, nature of soil** and **flora of the area.**

4. In the museums, the specimens are correctly identified, labelled, classified and stored. A catalogue of these specimens is prepared which helps in **future reference and taxonomical studies.**

5. These provide first hand information about the characters, identification, naming and classification of the organisms.

Importance of Botanical Gardens

Botanical gardens have important roles in the following fields :

1. Scientific and educational.
2. Pharmaceutical.
3. Horticultural.
4. Place of agreable public resort.

Botanical gardens keep records of local flora and are the sites of collection of living plant material for biosystematic studies. They also act as research stations to carry out studies on native flora and flora of other regions. Many gardens supply seeds and plant material for botanical studies. Many botanical gardens have developed documented collections of authenticated taxa.

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The gardens can also be used as conservatories. They also act as acclimatization centres for the introduction of economically useful plants.

KEYS

Keys represent the scheme for identification of plants and animals. Every taxonomore category like family, genus and species has separate taxonomic key. Separate taxonomic keys are required for each taxonomic category such as family, genus and species for identification purposes. Keys are generally analytical in nature. Such identification points are usually based on contrasting, clear-cut distinguishing characters.

Two types of keys can be discussed :

(a) Yolked or indented key

(b) Bracketed key

(a) Yolked or indented key. By this key, sequence of different choices between two or more statements of characters of a species is made available. Taxonomist is only to make the correct choice for the purpose of identification for example in family Ranunculaceae (a dicot family of Angiosperms) keeping in mind the carpel and fruit characteristics of different genera, identification is done.

(b) Bracketed key. Here for identification, pairs of contrasting statements are used. The key uses contrasting characters like indented but they are not separated by intervening subdividing characters each character is given a number in brackets.

REMEMBER

- **Some important Botanical Gardens of India and other countries are :**
  - **(i)** Lloyd Botanical Garden, Darjeeling (India)
  - **(ii)** Padua (Italy)
  - **(iii)** Pisa (Italy)
  - **(iv)** Leyden (Netherlands)
  - **(v)** Royal Botanic Garden, Kew (England)
  - **(vi)** Royal Botanic Garden, Edinburg (Scotland)
- One third of the total tiger population is in Madhya Pradesh, (India)
- Tiger being at the apex of food chain is a high profile symbol of richness of biodiversity.
- Some important museums are :
  - **(i)** American Museum of Natural History, New York (USA)
  - **(ii)** State Museum of Natural History, Stuttgarut, Germany
  - **(iii)** Bird Collection Museum of Natural History, Vienna, Austria
  - **(iv)** National Museum of Natural History, Barakhamba Road, New Delhi
  - **(v)** Museum of Mumbai Natural History, Mumbai
- Delhi zoo (established 1959), is located near old fort covers an area of 214 acres and exhibits about 22000 animals.
- Chhat Bir Zoological Park (established 1977) is located on Chandigarh-Patiala road covers an area of 200 ha and exhibits about 1300 animals.

Table 7. Differences between Zoological Park (Zoos) and Zoological Museums.

Characters	Zoological Parks	Zoological Museums
1. Life	For active and living organisms.	For lifeless and inactive specimens.
2. Place	Mostly in open, few in buildings.	Usually in buildings.
3. Entity	Whole animals are on show.	Animal parts/products/stuffed animals are on show.
4. Fossils	Not exhibited.	Can be exhibited.
5. Human evolution	Cannot be depicted.	Can be depicted with the help of models and charts.
6. Representation	All groups cannot be represented.	It is possible to represent all the groups in museums.

Table 8. Indented key in different genera of family Ranunculaceae.

Character of Identification	Genus identified
Carpel with one ovule :	
Fruit-achene, leaves opposite and compound, petals absent, leaves without tendril.	*Clematis*
Petals present, terminal (third) leaflet modified to form tendril.	*Naravelia*
Leaves radical or alternate	*Anemone*
Leaves simple, petals 5, basal placentation **Carpel with many ovules.**	*Ranunculus*
Fruit – follicle	*Nigella*
Carpels fused at base, regular flowers	*Aconitum*
Carpels free at base, irregular flowers.	

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Table 9. Bracketed key in family Ranunculaceae. Number written on right informs the next choice of paired contrasting statements.

Character of identification	Number for identification and genus identified
1. **Carpel** with one ovule, **fruit** achene.	(2)
1. **Carpel** with many ovules, **fruit** follicle.	(4)
2. **Leaves** opposite and compound	(3)
2. **Leaves** alternate and radical	*Anemone*
3. **Petals** in flowers absent and leaves without tendril	*Clematis*
3. Number of **sepals** and **petals** equal, terminal leaf forms tendril.	*Naravelia*
4. **Carpels** fused as base, regular flowers	*Nigella*
4. **Carpel** free (apocarpous), irregular flowers.	*Aconitum*

Identification in animals

Different characters in following vertebrates are :

Bat. Shows the presence of ear, wings and mammae.

Cat. Presence of hair, mammae, pinnae and tail.

Bird. Absence of hair, teeth and mammae. Presence of beak and wings.

Frog. Absence of gills, fins, pinna and scales. Presence of limbs.

Fish. Absence of limbs and pinnae. Presence of scales, gills.

Snake. Absence of limbs, pinnae, eye-lids. Presence of elongated body with scales.

IIere the questions are framed to get only one answer i.e. yes or no (Refer Table 18)

Couplet. The keys are taxonomic literature based on contrasting characters, generally a pair called couplet.

Lead. Key represents artificial analytical order/ arrangement with choice to be applied between two opposite options. This results in acceptance of only one and rejection of other. Each statement of key is known as lead.

Correct identification is further helped by :

(i) Manuals are useful in providing information for identification of names of species occuring in an area.

(ii) Monographs provide information for reversionary work particularly for taxa like family and genus of the unknown.

(iii) Flora accounts on habit and distribution of plants of given area. It provides index to the plants known in the area.

Table 8

Question	Option	Clue
1. Does it bear external ears?	Yes	Go to 2
	No	Go to 3
2. Does it fly?	Yes	Bat
	No	Cat
3. Does it fly?	Yes	Bird
	No	Go to 4
4. Does it bear limbs?	Yes	Frog
	No	Go to 5
5. Does it bear gills?	Yes	Fish
	No	Snake

ADDITIONAL USEFUL IMFORMATIONS ABOUT HERBARIA AND BOTANICAL GARDENS FOR COMPETITIVE EXAMINATIONS

- *Hooker compiled first complete flora of India.*
- *There are many good botanical gardens in the world e.g. Padua (Italy), Kew (England) and Missouri (USA).*
- *The largest herbarium of the world is at Kew (England).*
- *The plant collection exercise requires specific field equipment like diggers, pruning knife, vasculum and polythene bag, field notebook, plant press and folders.*
- *The largest herbarium of India is Central National Herbarium at Kolkata.*
- *Botanical Survey of India at Kolkata explores the plant wealth of India.*
- *An administrator of Nazib-ud-Daula, Zabita Khan developed a garden at Saharanpur which was improved by Govan in 1820.*
- *There is famous 'Shalimar Garden' at Srinagar.*

PRACTICE PROBLEMS – WILD LIFE

1. Who coined the term "wildlife"?
2. What is wildlife symbol of WWF?
3. Give the scientific importance of wildlife.
4. Which useful material is derived from the bark of *Cinchona* plant?
5. Name the most serious threat to wildlife.

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6. Which animal became extinct from India due to excess hunting?
7. What percentage of the living species of animals is threatened?
8. Name three categories of threatened species.
9. Give the full form of IUCN.
10. When does the wildlife week celebrated in India?
11. Which sanctuary is called an oasis of water birds?
12. Give the full form of MAB.
13. Name the zoo famous for white tigers.
14. Differentiate between flora and monograph.

ANSWERS TO PRACTICE PROBLEMS

1. William Hornday.
2. Red Panda.
3. Wildlife acts as gene bank and provides research materials to produce new varieties/species.
4. Anti-malarial drug-Quinine.
5. Destruction of habitats.
6. *Acinomyx jubatus* (cheetah).
7. Ten per cent.
8. Endangered; vulnerable and Rare species.
9. International Union for Conservation of Nature and Natural Resources.
10. First week of October.
11. Chilka lake bird sanctuary (Orissa).
12. Man and Biosphere Programme.
13. Nandankanan zoo (Orissa).
14.

Character	Flora	Monograph
1. Information	Provides information about all plants found in an area.	Provides detailed information about a taxon.
2. Description	Describes habitat, environment and taxonomic features of an area.	Describes description in world and diagnostic features of various members of taxon.

ADDITIONAL USEFUL INFORMATIONS ABOUT BIODIVERSITY FOR COMPETITIVE EXAMINATIONS

- ***William Hornday** : Coined the **term wildlife**, wrote the book **"Our Vanishing Wildlife"**.*
- *Human activities have hastened the extinction of many species which is otherwise a natural phenomenon.*
- *Marine plants are **main producers** and produce about **325 thousand million tonnes of dry biomass annually** out of 380 thousand million tonnes of dry biomass.*
- ***Some more endangered animal species of India :***

  A. Reptiles :
  - ***Water monitor : Varanus salavator.***
  - ***Tortoise shell turtle : Eretmochelys imbricata.***
  - ***Gavialis.***

  B. Birds :
  - ***Cheer pheasant : Catreus wallichii.***
  - ***Likh Florican : Sypheotides indica.***
  - ***White eyed duck.***

  C. Mammals :
  - ***Four horned rhinoceros : Tetracerus quadricornis.***
  - ***Sloth bear : Melurus ursinus.***
  - ***Indian wild dog : Canis alpinus.***
  - ***Golden cat : Felis temminki.***
- ***Out of danger (O)** : Those taxa which were earlier placed in one of three categories of threatened species but which are now considered relatively secure due to application of effective conservation methods.*
- ***Black buck** and **Hoope** are state mammal and bird of Punjab respectively.*
- ***Tiger** and **Peacock** are our **National animal** and **National bird** respectively.*
- ***World Conservation Day : 3rd December.***
- ***World Animal Day : 3rd October.***
- ***World Habitat Day : 4th October.***
- *India spends about 250 million dollars annually to repair the damage caused by floods.*

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- ***Endemic species :*** *A species found in a particular natural habitat only e.g.* ***Ficus religiosa, Butea monosperma,*** *etc.*
- ***Wildlife Institute of India :*** *Located at* ***Dehradun*** *(Uttrakhand).*
- *There are about* ***243 biosphere reserves*** *in 65 countries of the world.*
- ***Animal products*** *e.g.* ***lac*** *from* ***Laccifera lacca. Honey*** *and* ***wax*** *from* ***Apis dorsata, A. indica. Mulberry silk*** *from* ***Bombyx mori. Tassar silk*** *from* ***Anthrea paphita. Muga silk*** *from.* ***A. assama.***
- ***First Earth Summit*** *was held at* ***Rio de Janeiro*** *(Brazil) and was aimed at conservation of environment.*
- ***Ranganthitoo Sanctuary (Mysore) :*** *is famous for birds population.*
- *Tiger population in U.P. has increased by 20 to 423 as per 1997 census as compared to the 1995 census.*
- *Recently (1998), Chinese doctors and medical researchers have reported that the bones of mole rat can be an effective alternative to the tiger bones for Chinese medicines used for treating pain. This scientific breakthrough may curb tiger poaching and illegal trade in tiger parts.*
- ***In September, 1998,*** *about 544 endangered animals, including 40 rhinos, have been killed by poachers or drowned as the result of massive floods of about 18 feet deep in the 430 sq. km. area of world famous Kaziranga National Park, a world heritage site. Over 40 rhinos, 429 hog deers, 20 wild buffaloes, 8 swamp deers, 10 sambars, 17 wild boars, 4 elephants and many other animal species are feared dead between June and September. Of the 40 rhinos killed, 31 were drowned while nine were killed by poachers.*
- ***Tiger link :*** *A latest newsletter on tiger conservation reported several cases of tiger poisoning in the Corbett Tiger Reserve and Dudhwa Tiger Reserve of Uttrakhand in the months of December, 1997 and January, 1998.*
- ***Some special projects for endangered animal species :***
  - *Tiger project*
  - *Gir lion project*
  - *Crocodile breeding project*
  - *Rhino conservation project*
  - *Snow Leopard project.*
- ***Periyar wildlife sanctuary*** *is located at :* ***Idduki (Kerala).***
- ***Ranthambore National Park*** *is situated in* ***Rajasthan.***
- ***White tigers*** *are conserved in* ***Corbett National Park.***
- ***Flamingoes*** *in India are preserved at* ***Rann of Kachchh.***
- ***Orang National Park (Assam) :*** *One of India's youngest national park and home of the world's third largest population of the one horned rhinoceros. It covers only 78.8 sq. km. area.*
- ***Cultigens :*** *Domestic animals and cultivated plants both.*
- ***Whales*** *when washed ashore will die because their bones are crushed due to their own weight.*
- ***Dudhwa National Park*** *is located in* ***U.P.***
- ***Biosphere Reserve Project*** *was started in India since* ***1988.***
- ***SATYA : Save Tiger Youth Association***
- ***Dr. Salim Ali :*** *Great ornithologist of India.*
- ***King Ashoka :*** *First king to set up wildlife sancuaries.*
- ***World Environment Foundation (WEF) President : Madhar Mehra.***
- ***World Congress on Environment Management*** *was organised from June 1-3, 2000 at New Delhi. Its theme was* ***"Environment Management : The Key to Global Competitiveness and Improving Quality of Life"***
- ***Olive Ridley turtles :*** *A rare breed of fresh-water turtles scientifically called* ***Trionyx gangeticus*** *(commonly called* ***Ganges soft shells).*** *Earlier its breeding grounds were destroyed in Orissa. Now these face extinction in Assam's Cachar district due to rampant killing for its delicate meat.*
- ***National Institute of Oceanography*** *located at* ***Goa.***
- *India is perhaps the only country in the third world that has a strict legal framework for conservation of its natural resources including wildlife. Even then, the problems seem to be multiplying.*
- ***WWF-N announced 1998-99 as "year of Tiger"***
- ***Tiger cell :*** *A police-forest cell, first formed in Madhya Pradesh, to combat crimes against wildlife.*
- *In* ***January 2000,*** *single largest haul of animal parts in history was made when about 70 leopard skins, four tiger skins, 18,000 leopard claws and 221 black buck skins were seized in a little town of* ***Khaga*** *in Fatehpur district of U.P.*
- *To protect India's biodiversity, a bill was passed by Indian Parliament in December, 2003. Law was made to* ***Check biopiracy*** *and to prevent use of biodiversity by foreigners.*
- *In Chennai, a Biodiversity Board office has been established. The main task of Board is to make sure proper use of biodiversity. It also targets at equitable distribution of benefits made available by biodiversity.*

WORLD ENVIRONMENT DAY : 5TH JUNE, 2000
THEME
"2000 : THE ENVIRONMENT MILLENIUM — TIME TO ACT"

- *COUNTRY SYMBOLS BASED ON PLANTS/ANIMALS*
  - *Russia — White beer*
  - *Nepal — Rhododendron*
  - *China — Giant panda*
  - *U.S.A. — Bald eagle*

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- *India — Tiger*
- *U.A.E. — Phoenix*
- *Australia — Kangaroo*
- *New Zealand — Kiwi*

- ***Haryana has named all its tourists resorts after birds.***
- ***RECENT ACHIEVEMENTS :***
  - *The 12th Biosphere Reserve was set up* ***at Kanchenjuga Hills in Sikkim.***
  - *Assessment of forest cover of the country, finalised by the Forest Survey of India, indicates increase in the forest cover.*
  - ***Only unleaded petrol*** *is supplied in all retail oulets of the country with effect from* ***1.2.2000*** *and* ***0.25% sulphur in diesel*** *with effect from* ***1.1.2000*** *respectively. As a result of these efforts, air pollution in Delhi has been found to be reduced.*
  - ***Noise Pollution (Regulation and Control) Rules, 2000*** *under Environment Protection Act notified.*
- ***SPECIAL EMPHASIS ON IDENTIFIED THRUST AREAS :***
  - *Mangroves-Conservation and Management.*
  - *Bamboo Plantations to increase employment opportunities based on bamboo.*
  - *Coastal Shelter Belt for protection of the coastline from cyclonic winds.*
  - *Medicinal plants to conserve biodiversity and create employment opportunities.*
  - *Eco-Tourism in forests and wildlife sanctuaries.*
  - *Promotion and use of cleaner technologics for pollution control.*
  - *Wildlife Conservation.*
  - *Eco-Villages to ensure a better living standard for the rural masses.*
  - *Mass Awareness to spread consciousness on environmental issues.*
  - *Eco-Cities-afforestation drive for pollution control.*
  - *Management of Hazardous substances.*
  - *Shelf of Projects for External Assistance.*
  - *Environment Protection Fund.*
  - *Management of Waste Water.*
  - *National Forestry Action Programme to increase forest cover upto 33% of land area.*
- ***Nandankanan Zoo (Orissa) :*** *About 12 rare white tigers died in the month of* ***July, 2000*** *due to* ***Trypanosomiasis*** *caused by a protozoan* ***Trypanosoma*** *and spread by the insect bite. This zoo has the largest number of white tigers (about 28) in the world. It also has 26 other tigers. The death of the tigers in Nandankanan is a warning to conservationalists. It clearly shows that if we donot give them space and their natural prey,* ***the tiger will go the way of cheetah.***
- *The Zoological Society of San Diego has established a "****Frozen zoo****"to store samples of more than 355 species, including mammals, reptiles and birds.*

CHAPTER SUMMARY

- Living organisms show characteristics like growth, reproduction, metabolism, cellular organisation and consciousness.
- The number of species that are known and described range between 1.7 to 1.8 million.
- **Nomenclature** is only possible when the organism is described correctly.
- Each name has two components-the **genetic name** and **specific epithet.**
- The system of providing a name with two components is called **binomial nomenclature.**
- Biological names are generally in Latin and written in italics.
- **Classification** is the process by which anything is grouped into convenient categories based on some easily observable characters.
- The process of classification is called **taxonomy.**
- **Genus** comprises a group of related species, which has more characters in common in comparison to species of other genera.
- **Herbarium** is a store house of collected plant specimens that are dried, pressed and preserved on sheets.
- **Botanical gardens** are specialised gardens have collections of living plants for references.
- **Museums** have collections of preserved plants and animal specimens for study and reference.
- **Taxonomic keys** are tools that help in identification based on characters.

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KEY TERMS

Botanical garden	:	It is a place where there is assemblage of living plants maintained for botanical teaching and research purposes.
Binomial nomenclature	:	A system of two word names.
Biodiversity	:	It refers to variety and variability among living organisms and the ecosystem complexes in which they occur.
Blue book	:	UNEP has compiled endangered species of the world under the title 'Blue book'.
Biosphere reserve	:	A protected area where multiple use of the land is permitted by dividing into certain zones.
Conservation	:	The national management of and care for the biosphere in order to avoid the creation of imbalance resulting in the destruction of habitats and the extinction of species.
Deforestation	:	Destruction of forest *i.e.* denudation of forest area.
Endangered species	:	The species which are in danger of extinction and whose survival is unlikely, if causal factors continue operating.
***Ex-situ* conservation**	:	The conservation of components of biological diversity outside their natural habitats.
Extinction	:	Complete elimination of a population.
Exotic species	:	Powerful species introduced in a country from another country.
Genetic resources	:	Genetic material of actual or potential value.
Genetic diversity	:	It refers to the variation of genes within species.
Green book	:	It lists rare plants growing in protected areas like Botanic gardens.
Herbarium	:	It is a collection of well dried and nicely preserved plants after correct identification.
Herbarium sheets	:	The sheets of paper on which plants are mounted.
National parks	:	A protected area aimed at betterment of wild life but where human activities are not permitted.
National herbarium	:	The herbarium which covers flora of the world.
Red Data Book	:	Book containing a record of threatened animal species.
Sanctuary	:	A protected area aimed at conservation of only animals and where certain human activities are also permitted.
Rare species	:	Species with small population in the world. At present not endangered and vulnerable but are at risk.
Silviculture	:	Branch dealing with management of forests.
Threatened species	:	Species which have greatly reduced in their number or whose natural habitats have been disturbed so are near extinction.
Vulnerable species	:	The species likely to move into the endangered category if in near future the causal factors continue to operate.
Wildlife	:	All the living organisms other than cultivated plants and domesticated animals.

NCERT FILE Solved

NCERT Exercise Questions

1. Why are living organisms classified?

Ans. (i) Classification makes the study of living organisms **convenient**.

(ii) It helps in specific **identification** of various living beings.

(iii) It informs about the evolutionary relationship by establishing the gradually increasing complexity of form and structure in different groups of plants and animals.

2. Why are the classification systems changing every new and then?

Ans. (i) Organisms exhibit a great deal of variation in their form, structure, mode of life etc.

(ii) Sometimes more diversity is exhibited then suspected.

(iii) New classification may represent **better relationship** amongst organisms.

(iv) New changed system may be a **better incoherence** and definable characters.

3. What different criteria, would you choose to classify people, that you meet often?

Ans. (i) Levels of organisation

(ii) Types of organisation

(iii) Complexity of organism's body

(iv) Mode of obtaining nutrition.

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4. What do you learn from identification of individuals and populations?

Ans. It determines the correct place of an organism in a previously established plan of classification.

5. Given below is the scientific name of mango. Identify the correctly written name :

(i) *Mangifera Indica* **(ii)** *Mangifera indica*

Ans. *Mangifera indica*

6. Define a taxon. Give some examples of taxa at different hierarchical levels.

Ans. In classification, hierarchy of many steps are involved where each step represents a **rank** or **category**. Each category basically represents a **rank** and usually called an **taxon.**

For example refer Table 3.

7. Can you identify the correct sequence of taxonomical categories?

(a) Species → Order → Phylum → Kingdom

(b) Genus → Species → Order → Kingdom

(c) Species → Genus → Order → Phylum

Ans. (c).

8. Try to collect all the currently accepted meanings for the word "species". Discuss with your teacher the meaning of species of higher plants and animals on one hand and bacteria on other hand.

Ans. **Species** is a group of individuals in plants as well as animals which resemble closely in structure as well as in functions.

Species may be defined as population of individuals with similar structural and functional characteristics, which have common ancestry and in nature breed only with each other.

To understand better about meaning of species of higher organisms and bacteria, study Kingdom Monera, Kingdom Plantae and Kingdom Animalia of Five Kingdom System of Classification in Chapter 2.

9. Define and understand the following terms :

(i) Phylum (ii) Class (iii) Family (iv) Order (v) Genus

Ans. Refer taxonomic categories in this Chapter.

10. How is key helpful in the identification and classification of an organism?

Ans. A key provides a convenient way for easy identification of an organism by applying diagnostic or distinguishing characters.

11. Illustrate the taxonomical hierarchy with suitable examples of plant and animal.

Ans. Refer Table 3.

NCERT Exemplar Problems

A. MULTIPLE CHOICE QUESTIONS

1. As we go from species to kingdom in a taxonomic hierarchy, the number of common characteristics:
   (a) Will decrease (b) Will increase
   (c) Remain same (d) May increase or decrease
2. Which of the following 'suffixes' used for units of classification in plants indicates a taxonomic category of 'family'?
   (a) – Ales (b) – Onae
   (c) – Aceae (d) – Ae
3. The term 'systematics' refers to:
   (a) Identification and classification of plants and animals
   (b) Nomenclature and identification of plants and animals
   (c) Diversity of kinds of organisms and their relationship
   (d) Different kinds of organisms and their classification
4. Genus represents:
   (a) An individual plant or animal
   (b) A collection of plants or animals
   (c) Group of closely related species of plants or animals
   (d) None of these
5. The taxonomic unit 'Phylum' in the classification of animals is equivalent to which hierarchial level in classification of plants :
   (a) Class (b) Order
   (c) Division (d) Family
6. Botanical gardens and zoological parks have :
   (a) Collection of endemic living species only
   (b) Collection of exotic living species only
   (c) Collection of endemic and exotic living species
   (d) Collection of only local plants and animals.
7. Taxonomic key is one of the taxonomic tools in the identification and classification of plants and animals. It is used in the preparation of
   (a) Monographs (b) Flora
   (c) Both a & b (d) None of these
8. All living organisms are linked to one another because
   (a) They have common genetic material of the same type
   (b) They share common genetic material but to varying degrees
   (c) All have common cellular organization
   (d) All of above
9. Which of the following is a defining characteristic of living organisms?
   (a) Growth
   (a) Ability to make sound
   (a) Reproduction
   (a) Response to external stimuli
10. Match the following and choose the correct option:
    (A) Family i. *tuberosum*
    (B) Kingdom ii. Polymoniales

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(C) Order iii. *Solanum*
(D) Species iv. Plantae
(E) Genus v. Solanaceae

Options:

(a) i-D, ii-C, iii-E, iv-B, v-A
(b) i-E, ii-D, iii-B, iv-A, v-C
(c) i-D, ii-E, iii-B, iv-A, v-C
(d) i-E, ii-C, iii-B, iv-A, v-D

ANSWERS

1. (a); **2.** (c); **3.** (c); **4.** (c); **5.** (c); **6.** (c); **7.** (c); **8.** (d); **9.** (d); **10.** (a);

B. VERY SHORT ANSWER TYPE QUESTIONS

1. Linneaus is considered as Father of Taxonomy. Name two other botanists known for contribution in the field of plant taxonomy?

Ans. **(i) George Bentham** and **J. D. Hooker** gave important system of classification of angiosperms.

(ii) Eichler gave famous phylogenetic system of classification.

2. What does I C Z N stand for?

Ans. International Code for Zoological Nomenclature.

3. Couplet in taxonomic key means:

Ans. Contrasting characters.

4. What is a monograph?

Ans. A monograph bears descriptive information on any one taxon.

5. ***Amoeba*** **multiplies by mitotic cell division. Is this phenomena growth or reproduction. Explain.**

Ans. *Amoeba* is unicellular organism and reproduction is synonymous with growth. Here increase in number of cells occur.

6. Define metabolism.

Ans. Metabolism represents the sum total of all chemical reactions that take place in an organised and controlled fashion in living organisms. Metabolism is of two types i.e., anabolism and catabolism.

7. Which is the largest botanical garden in the world? Name a few well known botanical gardens in India.

Ans. Royal Botanic Garden (RBG), Kew (London) is the largest botanical garden in the world.

Few well known botanical gardens in India are:

(i) National Botanical Garden (NBG), Lucknow (UP).
(ii) Lloyd Botanical Garden, Darjeeling.
(iii) Indian Botanical Garden, Sib pur (Howrah), Kolkata (WB).

C. SHORT ANSWER TYPE QUESTIONS

1. A ball of snow when rolled over snow increases mass, volume and size. Is this comparable to growth as seen in living organisms? Why?

Ans. No, it is not comparable to growth in living organisms, because here growth is due to internal addition of protoplasmic materials by which cells enlarge and divide. However, non-living increase the size, weight etc. due to deposition of materials over the surface.

2. In a given habitat, we have 20 plant species and 20 animal species. Should we call this as 'diversity' or 'biodiversity'. Justify your answer.

Ans. Different types of plant and animal species in an area constitute biodiversity. Thus habitat with different 20 plant species and 20 animal species constitute the biodiversity.

3. International Code of Botanical Nomenclature (ICBN) has provided a code for classification of plants. Give hierarchy of units of classification, botanists follow while classifying plants and mention different 'Suffixes' used for the units.

Ans. Refer 'taxonomic categories' of this Chapter (Biological classification).

4. A plant species shows several morphological variations in response to altitude gradient. When grown under similar conditions of growth, the morphological variations disappear and all the variants have common morphology. What are these variants called?

Ans. These variations are known as morphological variations and the variants are called as biotypes.

5. How do you prepare your own herbarium sheets? What are the different tools you carry with you while collecting plants for the preparation of a herbarium? What information should a preserved plant material on a herbarium sheet provide for taxonomical studies?

Ans. A preserved plant material on herbarium sheet may provide information about species, genus, family, date of collection, area of collection etc. for taxonomic studies.

Further other details refer 'Making of Herbarium' of Chapter 1 (The Living World).

6. What is the difference between flora, fauna and vegetation? ***Eichhornia crassipes*** **is called an exotic species, while** ***Rauwolfia serpentina*** **is an endemic species in India. What do these terms exotic and endemic refer to?**

Ans. **(i) Flora.** It is plant life found in a region.

(ii) Fauna. It is animal life found in a region.

(iii) Vegetation. It is general term used for plant species of a region.

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Endemic species are indigenous species and are native to the environment, where they are found e.g. *Rauwolfia serpentina.*

Exotic species are introduced in an area from outer source e.g. *Eichhornia crassipes.*

7. **A plant may have different names in different regions of the country or world. How do botanists solve this problem?**

Ans. For solving the problem, binomial system of nomenclature given by Karl Von Linneaus should be used. In this system organism name constitutes two parts, first genus and second species.

8. **Brinjal and potato belong to the same genus *Solanum* but to two different species. What defines them as separate species?**

Ans. The biological name for brinjal is *Solanum melongena* and potato is *Solanum tuberosum.* They belong to same genus of family Solanaceae. But due to difference of certain characters like brinjal fruit is vegetable and produced above the ground and in potato, tubers (stem) are produced below the ground. They have been named with different species.

9. **Properties of cell organelles are not always found in the molecular constituents of cell organelles. Justify.**

Ans. Each cell organelle is made up of several constituent molecules like proteins, lipids, enzymes and metallic ions. All these molecules work together and perform a common function.

10. **The number and kinds of organisms is not constant. How do you explain this statement?**

Ans. Total number of organisms range between 5–30 million. Every year about 15000 new species are discovered. Many species become extinct. Variations form new material for evolution of new species. Reproduction and evolution bring changes in number of living organisms.

D. LONG ANSWER TYPE QUESTIONS

1. **What is meant by living? Give any four defining features of life forms.**

Ans. Refer Chapter 1 heading "What is Living"?

2. **A scientist has come across a plant, which he feels is a new species. How will he go about its identification, classification and nomenclature?**

Ans. One should the study the morphological and anatomical features in detail. Herbarium/botanical garden can further help in identification etc. Taxonomic keys provide necessary information in this regard.

3. ***Brassica campestris* Linn.**
   - **(a) Give the common name of the plant.**
   - **(b) What do the first two parts of the name denote?**
   - **(c) Why are they written in italics?**
   - **(d) What is the meaning of Linn. written at the end of name?**

Ans. (a) Mustard. (b) Genus and species.
(c) The biological names are written in italics as it is required by rules of nomenclature.
(d) Linn. at the end of name represents the name of the author, who discovered the plant for the first time.

4. **What are taxonomic aids? Give the importance of herbaria and museums. How are Botanical gardens and zoological parks useful in conserving biodiversity?**

Ans. The aids, which help in identification classification and nomenclature of plants and animals are called as taxonomic aids i.e. herbaria, botanical gardens, museums, zoological parks, monographs, manuals and research publications. For details of Botanical gardens and zoological parks refer the chapter.

5. **Define a taxon. What is meant by taxonomic hierarchy? Give a flow diagram from lowest to highest category of a plant and an animal. What happens to the number of individuals and number of shared characters as we go up the taxonomical hierarchy?**

Ans. Refer taxonomic categories of this chapter. Refer table 3 of this chapter for flow diagram. Number of shared characters and number of individuals get increased, when we go up with taxonomical hierarchy.

6. **A student of taxonomy was puzzled when told by his professor to look for a key to identify a plant. He went to his friend to classify what key the professor was referring to? What would the friend explain to him?**

Ans. Word 'Key' means here the taxonomic key. Taxonomic key is a device of diagnostic alternate characters which provide an easy method for identification of unknown organisms. The taxonomic keys help in identification, nomenclature and classification of newly discovered plant or animal.

7. **Metabolism is a defining feature of all living organisms without exception. Isolated metabolic reactions *in vitro* are not living things but surely living reactions. Comment.**

Ans. Metabolism is the sum of biochemical reactions that take place in the cells of organisms to sustain life. In a laboratory, chemical reactions usually occur and there is no requirement of isolating the products. The enzyme mediated biochemical reactions in living beings are highly selective and specific.

8. **Do you consider a person in coma – living or dead?**

Ans. In coma, a person is in deep state of unconsciousness. The person in coma is alive but not capable of responding or reacting to life around. The patient does not speak or obey commands. Thus in coma, a person can be considered as living dead.

9. **What is the similarity and dissimilarity between "whole moong dal" and "broken moong dal" in terms of respiration and growth? Based on these parameters classify them.**

Ans. In 'whole moong dal', when soaked in water, embryo (living) resumes normal life due to respiration and growth and forms seedlings. However, in 'broken moong dal', embryo is dead, no activity of respiration and growth are observed.

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HOTS Higher Order Thinking Skills & Brain Twisting

QUESTIONS WITH ANSWERS

Very Short Answer Questions *One mark each*

1. Who coined the term taxonomy?

Ans. de Candolle (1813).

2. Name the taxonomist to use the term species for the first time?

Ans. John Ray.

3. Who is classical taxonomist?

Ans. Classical taxonomist is the scientist dealing with the study of taxonomy of organisms in all aspects.

4. Mention the number of plants and animals described by Linnaeus.

Ans. Species Plantarum (1753)- 5900 plants; Systema Naturae (1758)- 4326 animals.

5. In which organism, the reproduction is synonemous with growth?

Ans. In unicellular organisms like *Amoeba,* bacteria and uncellular algae. Here increase in number of cells occur.

6. How is diversity in living world related to taxonomy?

Ans. The spectrum of diversity in the living world can be known only by the knowledge of taxonomy.

7. Who developed the concept of new systematics?

Ans. Julian Huxley (1914).

8. Expand ICZN.

Ans. International Code of Zoological Nomeclature.

Short Answer Questions *Two marks each*

1. Name the steps in process of taxonomy.

Ans. (i) Characterisation; (ii) Identification;
(iii) Classification; (iv) Nomenclature

2. Give examples of two species, having same genera.

Ans. (i) *Solanum tuberosum* (potato); *Solanum melongena* (brinjal).
(ii) *Panthera leo* (lion); *Panthera pardus* (leopard).

3. How *Amoeba, Planaria* and *Hydra* reproduce?

Ans. *Amoeba* - cell division; *Planaria* - Regeneration; *Hydra* - Budding.

4. What do you mean by typological concept of systematics?

Ans. It represents the study of one or few individuals to get information about all traits of a species.

5. Define category and hierarchy.

Ans. **Category:** It is unit of grouping of one rank used in taxonomy e.g. genus, family, order.
Hierarchy means arranging ranks or categories one above the other in particular order.

6. A ball of snow, when rolled over, snow increases in mass, volume and size. Is this comparable to growth as seen in living organisms? Why?

Ans. It is not the case of growth because size of ball is increasing due to addition of particles which is external. However in living organisms, growth takes place due to increase in material from inside of body.

Short Answer Questions *Three marks each*

1. Metabolic reactions can be shown outside the body in cell free systems experimentally. Why the cells are required in living oraganisms?
2. What makes species a basic taxonomic category?
3. How are plants and animals kept in museums?
4. How are living organisms divided into different taxa? What is the name given to this process?
5. Name the areas in which taxonomical aids are helpful. Which different types of taxonomical aids are used by taxonomists?

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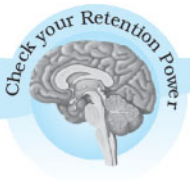
Long Answer Questions *Five marks each*

1. *Brassica campestris* Linn (i) Write the common name of plant (ii) What do the first two parts of name indicate? (iii) Why these are written in italics? (iv) What Linn indicates?
2. Define the following terms (i) Genus (ii) Species (iii) Family (iv) Class (v) Order.
3. What are obligate categories? How these differ from intermediate categories. Name some intermediate categories.

   Hint: The taxonomic categories which are always used in hierarchial classification of organism are called obligate categories. Examples of intermediate categories : Sub-phyla, sub-classes; sub orders; sub-families; sub-genera, varieties.



QUICK MEMORY TEST

A. Say True or False

Write "True" or "False".

1. Zoological parks are centres for recreation and education .
2. The indented key provides a sequence of choices between two or more characteristics.
3. Class is a category which includes related families.
4. *Amoeba* reproduces by budding.
5. Anabolism is the sum total of all constructive processes.
6. Cells are structural and functional unit of living organisms.

B. Complete the missing links

1. The humans have ..... sense organs which help them to sense the environment.
2. Biological names are generally in ..... and written in ..... .
3. Genus comprises group of related ..... .
4. ..... is a store house of collected plant specimens that are dried, pressed and preserved on sheets.
5. Zoological parks are the places where ..... animals are kept in protected environment.

C. Choose the correct alternative

1. **Flora/monograph** provides information as to all the plants growing in an area.
2. In **classical taxonomy/modern taxonomy**, a larger number of individuals are studied.
3. **Species/taxon** represents basic taxonomic category.
4. **Museum/zoological** park deals with living organisms.
5. In *Homo sapiens*, Homo represents **genus/order**.

Answers QUICK MEMORY TEST

A. Say True or False

1. True; 2. True; 3. False; 4. False; 5. True; 6. True.

B. Complete the missing links

1. Five; 2. Latin, italics 3. Species; 4. Herbarium; 5. Wild.

C. Choose the correct alternative

1. Flora; 2. Modern taxonomy; 3. Species; 4. Zoological park; 5. Genus.

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REVISION EXERCISES

Very Short Answer Questions — *One mark each*

1. Expand ICBN.
2. Expand ICZN.
3. Expand ICBacN.
4. Who gave the concept of New Systematics?
5. Define nomenclature.
6. Who coined the term taxonomy?
7. How many new species are described every year?
8. How many species of plants and animals have been named so far?
9. Define hierarchy.
10. Define category.

ANSWERS

1. International Code of Botanical Nomenclature; **2.** International Code of Zoological Nomenclature; **3.** International Code of Bacteriological Nomenclature; **4.** Julian Huxley (1940); **5.** Nomenclature provides proper, specific and distinguishing name to every organism; **6.** de Candolle (1813); **7.** 1500 species; **8.** 0.55 million species of plants and 1.25 million animal species; **9.** Hierarchy is the arrangement of ranks or categories one of the other in a particular order; **10.** Category is a unit of grouping of any rank used in taxonomy e.g. genus, family, order etc.

Short Answer Questions — *Two marks each*

1. What is metabolism? What are its types?
2. Write any two advantages of common names.
3. What are the disadvantages of common names?
4. Write any two advantages of binomial nomenclature.
5. How correlated characters help in defining genus?
6. What is the need of standardizing the names of living organisms?

ANSWERS

1. **Metabolism** represents the sum total of all the biochemical reactions taking place inside the living organisms. It is of two types.
   (i) **Anabolism:** It includes all the building up reactions;
   (ii) **Catabolism:** It constitutes breaking up reactions.
2. (i) Common names are easy to pronounce.
   (ii) They are short.
   (iii) Usually they represent some features of living organisms.
3. (i) A common name may have different meanings in different countries.
   (ii) Common names may have no relevance to its name e.g. Lady's finger.
   (iii) They may mislead e.g. jelly fish, silver fish, star fish are not fishes.
4. (i) Binomial nomenclature is not universally accepted.
   (ii) They are same in all languages.
   (iii) They indicate the relationship also.
5. Correlated characters are common features, which are used in delimitation of a taxon above the rank of species.
6. Usually, millions of organisms are known by local names which differ from place to place. Due to this, standard names of an organism is required all over the world.

Short Answer Questions — *Three marks each*

1. What different criteria, you choose to classify people that you meet often.
2. Write the common names and scientific names of following organisms:
   (a) Dog (b) Cat (c) Sparrow
3. Write the functions of an museum.
4. How does hierarchial system of classification help the scientist to unravel the mystery of living world?

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5. A scientist came across a plant, which he feels is a new species. How will he proceed towords its identification, classification and nomenclature?
6. Write the scope of systematics.
7. A plant may have different names in different regions of the country or world. How do botanists solve the problem?
8. All the organisms have not been yet identified. Justify the statement.

Long Answer Questions

Five marks each

1. What are the three major threat categories of species? Describe with examples.
2. Differentiate between two stages of metabolism.
3. Define the following terms:
   (i) Phylum (ii) Class (iii) Family (iv) Order (v) Genus
4. Explain the term of obligate categories. Discuss the various intermediate categories.
5. Describe the various taxonomic aids.
6. Write the rules and advantages of binomial nomenclature.
7. Discuss the various characteristics of living beings.

COMPETITION FILE OBJECTIVE TYPE QUESTIONS

A. MULTIPLE CHOICE QUESTIONS (MCQs):

(From AIPMT & Other Competitive Examinations)

1. In India, tropical rain forests occur in :
   (a) Jammu Kashmir (b) Andamans
   (c) Uttar Pradesh (d) Himachal Pradesh ***(MP-PMT 2010)***
2. The Central Wildlife Board was established in :
   (a) 1951 (b) 1955 (c) 1968 (d) 1970 ***(MP-PMT 2010)***
3. "Project Tiger" in India was launched in :
   (a) 1989 (b) 1975 (c) 1973 (d) 1968 ***(MP-PMT 2010)***
4. The total number of species, that are known and described range between :
   (a) 0.5 – 1.0 million (b) 1.1 – 1.2 million
   (c) 1.7 – 1.8 million (d) 2.5 – 3.0 million ***(DUMET 2010)***
5. The timing of seasonal activities of plants in relation to change in environmental condition is termed as :
   (a) Dendrochronology (b) Biological clock (c) Lapse rate (d) Phenology ***(DUMET 2010)***
6. The wildlife (protection) act 1972 was first amended in :
   (a) 1991 (b) 1995 (c) 2001 (d) 2007 ***(DUMET 2010)***
7. IUCN stands for :
   (a) Indian Union for Conservation of Nature (b) International Union for Conservation of Nature
   (c) Indian Union for Chemical Nomenclature (d) International Union for Conservation of Nutrients ***(DUMET 2010)***
8. The Indian rhinoceros is a natural inhabitant of which one of the Indian states?
   (a) Uttarakhand (b) Uttar Pradesh (c) Himachal Pradesh (d) Assam ***(CBSE 2010)***
9. An example of *ex situ* conservation is :
   (a) National Park (b) Seed Bank (c) Wildlife Sanctuary (d) Sacred Grove ***(AIPMT 2014)***
10. A location with luxuriant growth of lichens on the trees indicates that the :
    (a) Trees are very healthy (b) Trees are heavily infested
    (c) Location in highly polluted (d) Location is not polluted ***(AIPMT 2014)***
11. The organization which publishes the Red List of species is :
    (a) ICFRE (b) IUCN (c) UNEP (d) WWF ***(AIPMT 2014)***
12. New systematics introduced by Sir Julian Huxley is also called :
    (a) Phenetics (b) Cladistics (c) Biosystematics (d) Numerical taxonomy ***(J&K 2008)***

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13. Systema Naturae is written by :
(a) Linnaeus (b) Aristotle (c) Hippocrates (d) Darwin ***(Haryana 2008)***

14. Binomial nomenclature was first issued in :
(a) Systema Naturae (b) Genera Plantarium (c) Genera Animalium (d) Historia Plantarium ***(Haryana 2008)***

15. Systematic botany means :
(a) System analysis
(b) Systematic arrangement of organs of plants
(c) Systematic study of plants dealing with identification
(d) Naming and classification study of plants in gardens ***(J and K 2009)***

16. The basic unit of classification is :
(a) Species (b) Genus (c) Family (d) Phylum ***(J&K 2011)***

17. The term taxonomy is introduced by :
(a) De Candolle (b) Bentham and Hooker (c) Linnaeus (d) Huxley ***(J&K 2011)***

18. The framework system of classification in which various taxonomic categories are arranged in order of logical sequence is called :
(a) Systematics (b) Classification (c) Hierarchy (d) Taxon ***(J&K 2011)***

19. Scientific study of diversity of organisms and their evolutionary relationships is called :
(a) Morphology (b) Anatomy (c) Taxonomy (d) Systematics ***(J&K 2011)***

20. Select the incorrect statements :
(A) Lower the taxon, more are the characteristics that the members within the taxon share.
(B) Order is the assemblage of genera which exhibit a few similar characters.
(C) Cat and dog are included in the same family Felidae.
(D) Binomial nomenclature was introduced by Carolus Linnaeus
(a) A, B and C (b) B, C and D (c) A and D
(d) C and D (e) B and C ***(Kerala 2011)***

21. Which of the 4 names are correctly written as per rules of binomial nomenclature?
(a) SOLANUM MELONGENA (b) *Solanum melongena*
(c) Solanum Melongena (d) solanum melongena ***(COMEDK 2015)***

22. Which of the following is correctly matched with its particular taxonomic category?
(a) *Triticum aestivum* – Species (b) Fishes- Pisces –Phylum
(c) Man – Primate – Family (d) Mango- Sapindales-Class ***(COMEDK 2015)***

23. The formation of two species from one ancestral species is known as:
(a) Convergent evolution (b) Phyletic evolution
(c) Allopatry (d) Divergent evolution ***(Karnataka CET 2015)***

24. Who gave the nomenclature according to which humans are called *Homo sapiens*?
(a) Darwin (b) Mendel (c) Aristotle (d) Linnaeus ***(Bihar CECE 2015)***

25. Nomenclature is governed by certain universal rules. Which one of the following is contrary to the rules of nomenclature?
(a) Biological names can be written in any language
(b) The first word in a biological name represents the genus name, and the second is a specific epithet
(c) The names are written in Latin and are italicised
(d) When written by hand, the names are to be underlined. ***(NEET–I 2016)***

26. All of the following are included in 'Ex-situ conservation' *except*:
(a) Sacred groves (b) Botanical gardens (c) Wildlife safari parks (d) Seed banks ***(NEET 2018)***

27. Match the items given in Column I with those in Column II and select the ***correct*** option given below:

Column I	Column II
(a) Herbarium	i. It is a place having a collection of preserved plants and animals.
(b) Key	ii. A list that enumerates methodically all the species found in an area with brief description aiding identification.
(c) Museum	iii. Is a place where dried and pressed plant specimens mounted on sheets are kept.
(d) Catalogue	iv. A booklet containing a list of characters and their alternates which are helpful in identification of various taxa.

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	a	b	c	d
(a)	iii	ii	i	iv
(c)	i	iv	iii	ii

	a	b	c	d
(b)	ii	iv	iii	i
(d)	iii	iv	i	ii

(NEET 2018)

ANSWERS

1. (b);	**2.** (a);	**3.** (c);	**4.** (c);	**5.** (d);	**6.** (a);	**7.** (b);	**8.** (d);	**9.** (b);	**10.** (d);
11. (b);	**12.** (c);	**13.** (a);	**14.** (a);	**15.** (c);	**16.** (a);	**17.** (c);	**18.** (c);	**19.** (d);	**20.** (c);
21. (b);	**22.** (a);	**23.** (d);	**24.** (d);	**25.** (a);	**26.** (a);	**27.** (d)			

B. CBSE - PMT (MAIN EXAMINATION) QUESTIONS :

1. (i) Mention the main reasons for maximum bio-diversity in tropical rain forests.
(ii) Give the full form of IUCN.
(iii) What do you mean by sacred groves. Name such groves in Meghalaya, Rajasthan and Madhya Pradesh.
(iv) When, where and in which country earth summit was held? ***(CBSE 2009)***

Ans. (i) The main reasons for maximum biodiversity in tropical rain forests are :
(a) Tropical rainforests receive almost 12 hours of sunlight everyday. As there is plenty of sunlight, there is also a great amount of energy locked up in the rainforest.
(b) There are more places for plants to grow and animals to live. Since all their needs are met in the canopy.

(ii) International Union for Conservation of Nature and Natural Resources.

(iii) Sacred groves in India represents forest fragments of different sizes, which are communally protected and which usually have a significant religious connection for the protecting community. Hunting etc. are prohibited with in such areas.

Meghalaya : West Garo hills, East Garo hills, South Garo hills, Ri Bhoi, West Khasi and Jaintia hills.

Rajasthan : Jain Samadhi, Radha Krishna Temple, etc. (Ajmer-district), Viratra Kiaan (District-Barmer), Aashapoorna Devi Ki Oxan (Distt-Jaisalmer), Darodji, Deendayal Upadhyay park (Distt-Udaipur).

Madhya Pradesh : Devkot Matikot, Devsthali Budhadev.

(iv) The United Nation conference on Environment and Development 92 or the Earth Summit attracted 25,000-45,000 people at Rio de Janeiro (Brazil) in June 1992.

C. MATCHING TYPE QUESTIONS :

1. Match the columns :

Column A	Column B
(i) Taxonomy	(a) Order
(ii) Primata	(b) Descending arrangement of categories
(iii) Julian Huxley (1940)	(c) *Solanum*
(iv) Hierarchy	(d) Carolus Linnaeus
(v) Brinjal and potato	(e) Kingdom
(vi) Father of binomial nomenclature	(f) de Candolle (1813)
(vii) Highest category	(g) New Systematics
	(h) John Ray

ANSWERS

(i) (f); **(ii)** (a) **(iii)** (g) **(iv)** (b) **(v)** (c) **(vi)** (d) **(vii)** (e)

D. ASSERTION TYPE QUESTIONS :

These questions consist of two statements each, printed as Assertion and Reason. While answering these questions, you are required to choose any one of the following four responses.
A. If both Assertion and Reason are true and Reason is a correct explanation of the Assertion.
B. If both Assertion and Reason are true but Reason is not a correct explanation of the Assertion.
C. If Assertion is true but Reason is false.
D. If both Assertion and Reason are false.

1. Assertion : In wildlife conservation, there is no need to conserve micro-organisms.
Reason : Micro-organisms are not of much importance to mankind.
A **B** **C** **D**

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2. **Assertion** : Rate of extinction of wildlife has become rapid in the last one hundred years.
   Reason : Unplanned human activities like population explosion, deforestation, industrialization, hunting, etc. have destroyed the natural habitats of many spp. of wildlife
   A **B** **C** **D**
3. **Assertion** : Golden langur is a vulnerable species.
   Reason : Their number has reduced and their natural habitat is also disturbed.
   A **B** **C** **D**
4. **Assertion** : For the management of wildlife, environmental pollution must be checked.
   Reason : Environment provides the life supporting systems to wildlife.
   A **B** **C** **D**
5. **Assertion** : National parks have been set up to protect wildlife.
   Reason : Biosphere reserves have greater importance than the national parks.
   A **B** **C** **D**
6. **Assertion** : High yielding variety of rice was produced in India by introduction of dwarfing genes called Dee–goo–woo–gen from Taiwan.
   Reason : High yielding variety of wheat was produced from dwarfing genes of Norin–10 from Japan in India.
   A **B** **C** **D**
7. **Assertion** : In potato tubers stem is edible.
   Reason : Potato tubers are full of stored food material which bear leaves and fruits on them.
   A **B** **C** **D**
8. **Assertion** : Cotton and jute are fibre yielding plants.
   Reason : Cotton is obtained from seed hair (lint) and jute fibres are obtained from stalks of retted jute.
   A **B** **C** **D**
9. **Assertion** : With few exceptions, tropics harbour more species than temperate or polar areas.
   Reason : Species diversity decreases as we move away from the equator towards the poles.
   A **B** **C** **D** ***(AIIMS 2009)***

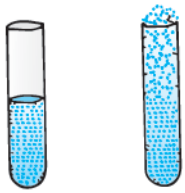
ANSWERS

1. D; 2. A; 3. C; 4. A; 5. B; 6. B; 7. D; 8. A; 9. A.

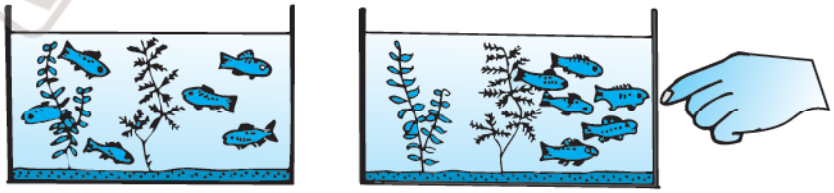
E. ADDITIONAL MULTIPLE CHOICE QUESTIONS :

Choose the correct answer :

1. Some yeast, sugar and water are mixed in a test-tube.
   The diagrams show the test-tube at the start and after one hour.
   Which process causes this change?



   (a) Growth (b) Irritability
   (c) Reproduction (d) Respiration
2. Excretion, irritability and reproduction are characteristics of :
   (a) All animals and plants (b) Animals only
   (c) Plants only (d) Some animals and some plants only
3. Which one of the following functions is carried out by green plants but not by animals?
   (a) Excretion (b) Growth
   (c) Photosynthesis (d) Respiration
4. Figure shows how fish react when the glass on one side of an aquarium tank is tapped with a finger.



   What characteristics of living organisms does this demonstrate?
   (a) Excretion and movement. (b) Excretion and nutrition
   (c) Growth and irritability. (d) Irritability and movement.

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5. Which is correct hierarchical sequence?
   (a) Phylum, class, order, family (b) Phylum, division, family, class
   (c) Genus, species, order, family (d) Division, order, class, genus.
6. A group of related genera represent
   (a) Species (b) Taxa (c) Order (d) Family
7. Scientific study of diversity and evolutionary relationships of organisms is called
   (a) Systematics (b) Anatomy (c) Taxonomy (d) Morphology
8. Botanical gardens provide:
   (a) Natural habitat to wildlife (b) Beautiful area for recreation
   (c) *Ex-situ* conservation of germplasm (d) Repository of tropical plants
9. Which one has a real existence?
   (a) Kingdom (b) Phylum (c) Genus (d) Species
10. The living organisms can be unexceptionally distinguished from the non- living things on the basis of their ability for
   (a) Reproduction (b) Growth and movement
   (c) Responsiveness to touch (d) Interaction with environment and progressive evolution
11. New systematics introduced by Sir Julian Huxley is also called
   (a) Biosystematics (b) Phenetics (c) Cladistics (d) Numerical taxonomy
12. Largest herbarium of India is at
   (a) Lloyd Botanical Garden, Darjeeling (b) Indian Botanical Garden, Sibpur
   (c) National Botanical Garden, Lucknow (d) Forest Research Institute, Dehradun
13. A condition in which internal environment of the body remains constant is
   (a) Hematoma (b) Haemopoiesis (c) Homeostasis (d) Hemostasis
14. Which one is taxonomic aid for identification of plants and animals based on similarities and dissimilarities
   (a) Flora (b) Keys (c) Monographs (d) Catalogues (e) Manuals
15. *nigrum* is one species of genus
   (a) *Mangifera* (b) *Solanum* (c) *Triticum* (d) *Pisum*
16. Binomial nomenclature was proposed by
   (a) Bauhin (b) Linnaeus (c) Huxley (d) de Vires
17. Royal Botanical Garden, Kew is located in
   (a) Germany (b) France (c) England (d) India
18. Which taxonomic aid gives comprehensive information about a taxon
   (a) Taxonomic key (b) Herbarium (c) Flora (d) Monograph
   (e) Dictionary
19. The basic unit of taxonomy is
   (a) Class (b) Order (c) Genus (d) Species
20. Which is not correct
   (a) Herbarium houses dried, pressed and preserved plant specimens
   (b) Botanical gardens have collection of living plants for reference
   (c) Museum has collection of photographs of plants and animals
   (d) Key is taxonomic aid for identification of specimens
21. Taxon is a unit of
   (a) Order (b) Genus (c) Species (d) Taxonomy

ANSWERS

1. (d); 2. (a); 3. (c); 4. (d); 5. (a); 6. (d); 7. (a); 8. (c); 9. (d); 10. (a);
11. (a); 12. (b); 13. (c); 14. (b); 15. (b); 16. (b); 17. (c); 18. (d); 19. (d); 20. (c);
21. (d).

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Chapter Practice Test

Time Allowed : 1:30 Hours *Maximum Marks : 35*

1. What is monograph? (1)
2. Couplet in taxonomic key means. (1)
3. Find out the odd one: (1)
   (i) Family, Class, Taxon, Phylum
   (ii) *indica, Ficus, Mangifera, Brassica*
   (iii) Plantae, Chordata, Tracheophyta, *Eucalyptus*
4. Which of the following cover the greater number of organisms: (1)
   (i) Family or Phylum
   (ii) Family or Order
   (iii) Class or Phylum
5. Name the basic unit of classification. (1)
6. What is biological diversity? (2)
7. Name the largest botanical garden in the world. Name any two well known botanical gardens in India (2)
8. Write the advantages of hierarchial system of classification. (2)
9. Mention three characteristics which distinguish living beings from non-living. (2)
10. How can we relate metabolism with growth? (2)
11. Name the suffix used for family, order and class. (3)
12. Why are classification systems changing every now and then? (3)
13. Illustrate the taxonomical hierarchy with suitable examples of a plant and an animal. (3)
14. Why biologists do not favour common names? (3)
15. Write briefly about flora and monograph. (3)
16. Compare taxonomy and systematics. Write briefly about classical taxonomy and modern taxonomy. (5)

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To check your performance, see ANSWERS TO CHAPTER PRACTICE TEST at the end of Part I of the book.

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CHAPTER 2

BIOLOGICAL CLASSIFICATION

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NEED FOR CLASSIFICATION

How many species exist on our planet? This is not easy question to answer. About 1.8 million species have been given the scientific names. Total number of estimated species range between 10 to 100 million. Many of them will become extinct before counted and identified. The leading naturalists of 18th and 19th centuries spent their lives identifying and describing newly described plants and animals. Scientists involved in this task are called **taxonomists.** Any systematic study on any organism can be made easier only, when organism is identified. Organisms exhibit a great deal of variation in their form, structure, mode of life etc. Unless the identified plants and animals are divided into distinct groups based on similarities and differences between them, it becomes almost impossible to study them.

Classification is the scientific practice of identifying, naming and grouping of living organisms. The branches of Biology, which deals with classification are called **taxonomy** and **systematics.**

Since Darwin's time, biological classification has come to understood as reflecting evolutionary distances and relationships between organisms. The creatures of our time had common ancestors in the past. Basically, they are the members of the same family tree. The huge diversity in organisms is mainly due to **adaptive radiation** or **branching evolution** (Fig. 1). This is the diversification of a species into different lines as they adapt to new **ecological niches** and finally evolve into distinct species.

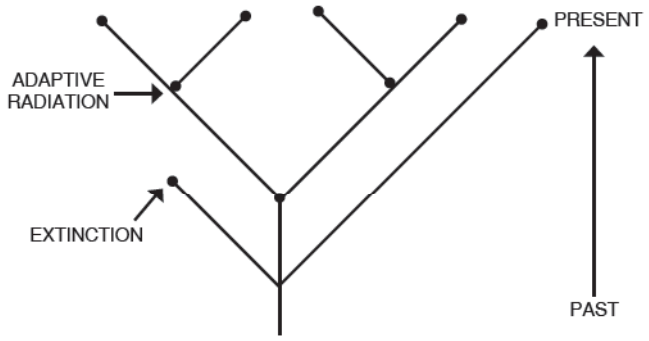

Fig. 1. Branching evolution.

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The advantages of biological classification are :

(i) Classification makes the study of living organisms **convenient.**

(ii) **Relationships** among various groups of organisms is revealed by classification.

(iii) It helps in **specific identification** of various living beings.

(iv) The study of few representatives from each group helps to **integrate the idea of life** as a whole.

(v) Biological classification gives knowledge about organisms which are found in **specific geographical regions.**

(vi) It informs about the **evolutionary relationship** by establishing the gradually increasing complexity of form and structure in different groups of plants and animals.

The incredible diversity of life on this planet, most of which is microbial, is best understood in an evolutionary framework—**Carl Woese, 2000.**

THREE DOMAINS OF LIFE

Until comparatively recently, living organisms were divided into two kingdoms : the **Animalia** and the **Plantae.** The scheme most often used currently divides all living organisms into **five kingdoms: Monera** (bacteria), **Protista, Fungi, Plantae,** and **Animalia.** This coexisted with a scheme dividing life into two main divisions: the Prokaryotae (bacteria, etc.), and the Eukaryotae (animals, plants, fungi, and protists).

Recent work, however, has shown that what were once called "prokaryotes" are far more diverse than anyone had suspected. The Prokaryotae are now divided into two domains, the **Bacteria** and the **Archaea,** as different from each other as either is from the **Eukaryota,** or eukaryotes (three domains of life). No one of these groups is ancestral to the others, and each shares certain features with the others as well as having unique characteristics of its own.

The **three domain system** is a biological classification given by **Carl Woese** (1990) a professor in the Department of Microbiology, University of Illinois. Dr. Woese proposed that there should be a new category of classification of life—the **domain,** a classification category above kingdom. Woese, C.R., O. Kandler and M.L. Wheeles (1990) in publication "Proposal for the domains Archaea, Bacteria and Eucarya" in Proc. Natl. Acad. Sci. USA 87 : 4576-4579 gave this system of classification. **In five kingdom system of classification nothing is said about how organisms within kingdoms may be related to each other.** It divides various organisms into (Fig. 2) :

(a) **Archaea** (b) **Bacteria** (c) **Eukaryote**

The three domain system is loosely based on traditional five kingdom system but divides the Monera into two "domains" leaving the remaining eukaryotic kingdoms in the third domain.

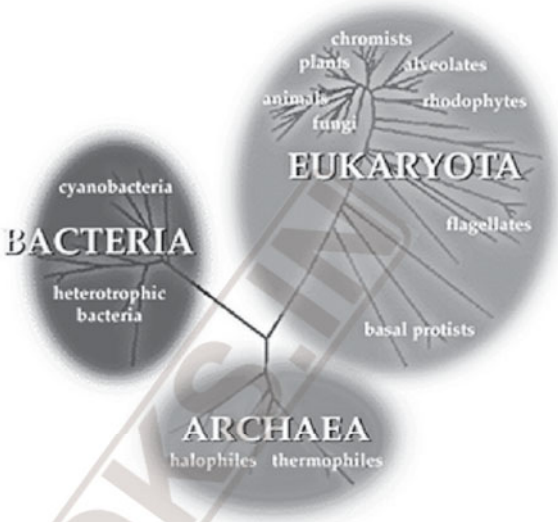

Fig. 2. Three domains of life.

Carl Woese won the National Medal of Science in November 2000.

1. Domain Archaea

(i) No nuclear membrane, prokaryotic.

(ii) Bear unique ancient evolutionary history for which they are considered some of the oldest species of organisms on earth.

(iii) With distinct biochemistry and RNA markers from eubacteria.

(iv) Found in the harshest environments on earth. Appearing in fossil record over 3.6 billion years ago.

(v) Most of the archaeans donot look different from bacteria under microscope, however, biochemically and genetically they are as different from bacteria as you are.

(vi) They are found in most extreme environments of the planet.

Kingdom archaebacteria

Examples :

(i) Methanogens (methane makers)

- Metabolizes hydrogen and carbon dioxide into methane.
- Live in swamps, marshes, gut of cattle, termites etc.

(ii) Halophiles (salt lovers)

- Thrive in salt.
- Live in Dead Sea, the Great Salt Lake, Salt evoporation ponds.

(iii) Thermoacidophiles (temperature/acid lovers)

- Prefer temperature above 60° C or near or below freezing.

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- Live in hot sulphur springs, ocean waters around Antarctica, under the polar caps.

2. Domain Bacteria

(i) No nuclear membrane, prokaryotic traditionally called bacteria.

(ii) Many are decomposers, some are photo-synthesizers and few cause disease.

(iii) Most bacteria cause diseases by producing toxins that harm human cells, others cause illness as a result of glycoproteins found on the out side of their capsules.

Kingdom eubacteria

Examples of two major divisions or phyla are :

(i) Cyanobacteria. Photosynthetic blue green bacteria.

(ii) Spirochaete. Gram negative bacteria that include those causing syphilis and Lyme disease.

(iii) Firmicutes. Gram positive bacteria including *Bifidobacterium animalis* which is present in human large intestine.

3. Domain Eukarya (Eukaryota)

(i) Eukaryotes

(ii) Bear nuclear membrane

Four kingdoms of eukaryotes are :

(i) Kingdom Protista

Examples :

- Rhodophyta – red algae
- Chromalveolata – includes dinoflagellates

(ii) Kingdom Fungi

Examples :

- Saccharomycotina – includes true yeasts
- Basidiomycota – includes shiitake mushrooms

(iii) Kingdom Plantae

Examples :

- Bryophyta – mosses
- Magnoliophyta – flowering plants

(iv) Kingdom Animalia

Examples :

- Arthropoda – includes insects, arachnids, and crustaceans.
- Chordata – includes vertebrates and, as such, human beings.

Table 1. Characteristics of three domains of life.

Characteristic	Bacteria	Archaea	Eukaryotes
	Archaea resemble Bacteria		
Cell volume	1 to 100 μm^3 (usually)		1 to 10^6 μm^3
DNA chromosome	Circular (usually)		Linear
Gene organization	Multi-gene operons; few introns		Single genes; Many introns
Metabolism	Denitrification, N_2 fixation, lithotrophy, respiration and fermentation		Respiration and fermentation
Nuclear membrane	None (nucleoid)		Nuclear membrane
Multicellularity	Simple		Complex
			Archaea resemble Eukaryotes
Monomolecular cell wall	Peptidoglycan (nearly always)		Absent in most species (Methanogens have pseudopeptidoglycan)
Ribosome sensitivity to Cam, Kan, and Str	Sensitive		Resistant
Translation initiator RNA polymerase	Formyl-Met Bacterial		Methionine (except mitochondrial F-Met) Eukaryotic
Transcription factors	Bacterial		Eukaryotic
	Archaea Differ from Bacteria and Eukaryotes		
Methanogenesis	No	Yes	No
Highest temperature growth	> 90°C	> 110°C	> 60°C
Photosynthesis	Many species. Bacteriochlorophyll	Halobacteria only; bacteriorhodopsin	Many species; bacterial origin. Chlorophyll, in Chloroplasts (prokaryotic in organization)
Chlorophyll light absorption	Red and blue	Green	Red and blue
Membrane lipids (major)	Ester-linked fatty acids	Ether-linked isoprenoids	Ester-linked fatty acids

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FIVE KINGDOM SYSTEM

A **five-kingdom system** is proposed here, based both on levels of organization and on types of organization as evolved in relation to three principal means of **nutrition—photosynthesis, absorption** and **ingestion.**

Five-kingdom system of classification was advanced by **R.H. Whittaker** (Science, 163 : 150-160, 1969). This system replaced the old, two-kingdom grouping of living organisms. As already discussed, a division of living world merely into plant and animal kingdoms is too simple. It does not take into account the **gradual** evolution of distinct plant and animal groups and it allows no place for those primitive organisms that even now are neither plants nor animals nor that are both.

Five-kingdom classification of **Whittaker** is based on the following three criteria :

1. Complexity of cell structure.
2. Complexity of organism's body.
3. Mode of obtaining nutrition.
4. Phylogenetic relationship.

The five kingdoms are :

1. **Monera**
2. **Protista**
3. **Plantae** (plants)
4. **Fungi**
5. **Animalia** (animals)

In this five-kingdom classification, the subdivisions of old two-kingdom classification have not been changed. And this particular arrangement depicts the phylogeny of various life styles better.

Table 2. Characteristics of Five Kingdom of Classification.

S.No.	Characters	Monera	Protista	Fungi	Plantae	Animalia
1.	**Type of nucleus**	Prokaryotic	Eukaryotic	Eukaryotic	Eukaryotic	Eukaryotic
2.	**Mitochondria**	Absent	Present	Present	Present	Present
3.	**Plastids (Chloroplast)**	Absent	Present in some cases	Absent	Present	Absent
4.	**Cell wall and Chemical nature**	Non-Cellular (Polysaccharide + Amino Acid)	Present in some (various type)	Present (Non-Cellulosic)	Present (Cellulose)	Absent
5.	**Nuclear membrane**	Absent	Present	Present	Present	Present
6.	**Multicellularity**	Absent	Absent	Present but limited	Present	Present
7.	**Motility**	By flagella, gliding or non motile	By cilia, flagella, amoeboid, contractile fibrils	By cilia, flagella in some or mostly non-motile	By cilia and flagella in lower forms, mostly absent	By cilia, flagella, contractile fibrils
8.	**Nutrition**	Autotrophic (chemosynthetic and photosynthetic), heterotrophic (saprophyte or parasite)	Photosynthetic or heterotrophic	Heterotrophic (saprophytic or parasitic, absorption)	Autotrophic (Photo-synthesis)	Heterotro-phic (Holozoic/ saprophytic)
9.	**Sexual reprod-uction**	Conjugation, Transduction, Transformation or none	By syngamy followed by meiosis, conjugation or none	Fertilization followed by meiosis or none, Dikaryons may be formed	Fertilization followed by meiosis	Fertilization followed by meiosis
10.	**Nervous system**	Absent	Primitive for conduction of stimuli	Absent	Absent	Present, usually complex.

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KINGDOM MONERA

(The Prokaryotes)

Monera (*monos*—single) includes prokaryotes and shows the following characters :

1. They lack nuclear membranes.

2. They are devoid of plastids, mitochondria and advanced (9+2 strand) flagella.

3. They are typically unicellular organisms (but one group is mycelial).

4. The predominant mode of nutrition is absorptive but some groups are photosynthetic or chemosynthetic.

5. Reproduction is primarily asexual by fission or budding.

6. Protosexual phenomenon also occurs.

7. The organisms are non-motile or move by beating of simple flagella or by gliding.

8. Moneran cells are microscopic (1 to few microns in length).

9. Most organisms bear a rigid cell wall.

Nutrition in Kingdom Monera

They show both autotrophic and heterotrophic modes of nutrition.

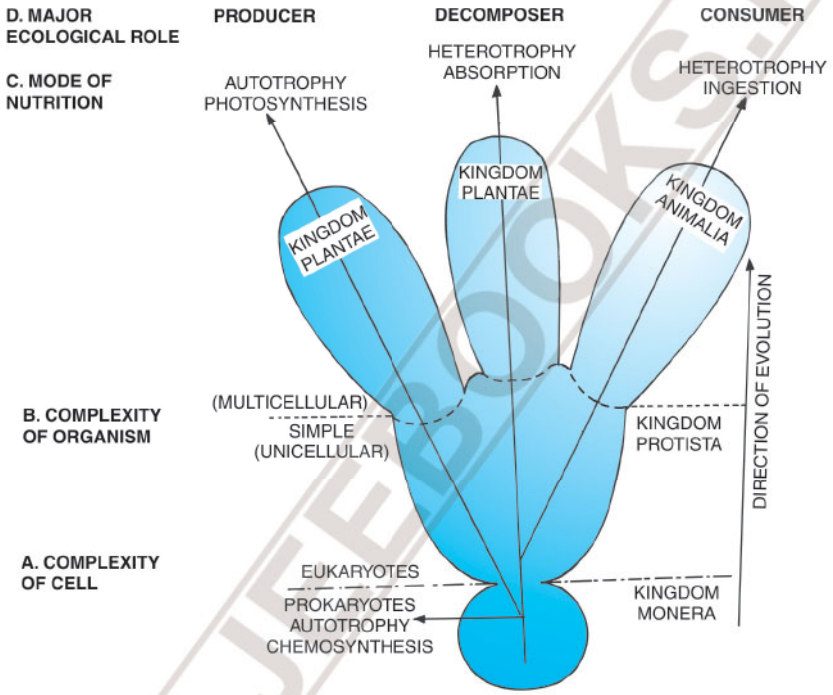

Fig. 3. The five kingdoms of life. The kingdoms are arranged to show the probable phylogenetic relationships among the kingdoms, based on fossil and other evidences. Such an arrangement allows us to visualize increase of complexity with evolutionary time and divergence of the three modes of nutrition in the three multicellular kingdoms (plants, fungi, animals).

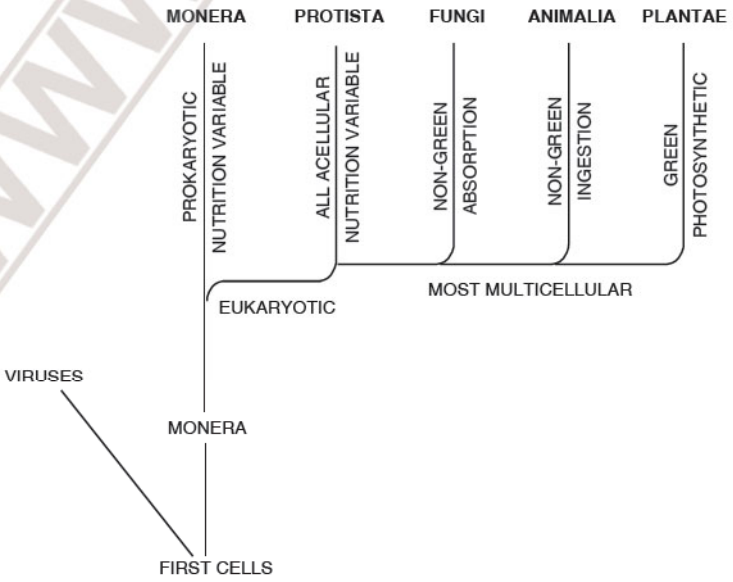

Fig. 4. Phylogenetic relationship of five kingdoms.

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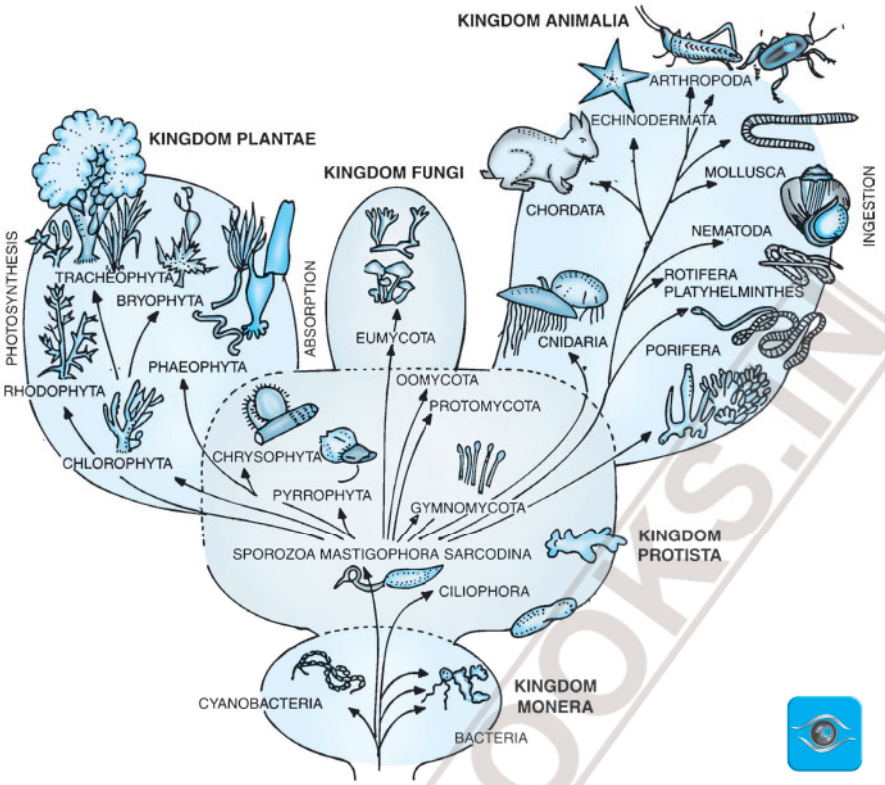

Fig. 5. The five kingdoms of life showing the major phyla and their probable evolutionary relationships (lines and arrows). The dotted line separates the prokaryotic kingdom (monera) from the eukaryotic kingdoms (Protista, Plantae, Fungi and Animalia). The arrangement of the multicellular kingdoms (Plants, Fungi, Animals) indicates how they may have evolved from the primarily unicellular Kingdom Protista.

Autotrophs. These are able to form their own food by one of the following methods :

(a) Photoautotrophs. They prepare their own food by reducing CO_2 using light energy.

(b) Chemoautotrophs : They form their food by energy derived from chemical reactions.

Heterotrophs. A few live in **symbiosis** while others form association of **commensalism. Saprophytes** cause decay, fermentation or putrefaction of dead organic matter. In the process of **fermentation** there is anaerobic break-down of carbohydrates into CO_2, alcohol and some energy. **Putrefaction** or decay is anaerobic break-down of proteins accompanied by foul smell due to evil smelling gases produced in the process.

The saprobes produce enzymes which convert non-diffusible food substrates (carbohydrates, fats, proteins etc.) into simpler diffusible form which diffuses into the cytoplasm and is assimilated, *i.e.*, converted into body cytoplasm or stored as reserve food.

Still others live on other living organisms (animals, plants or man) in the form of parasites and directly absorb their food from the body of host. Some of the parasites are **non-pathogenic** *i.e.* cause no ill-effect or disease in the host, while some are **pathogenic** causing diseases in the host.

ARCHAEBACTERIA

Archaebacteria exhibit the following characters :

(i) They are found at most harsh habitats like :
- **(a)** Extreme salty areas (**halophiles**)
- **(b)** Hot springs (**thermo-acidophiles**)
- **(c)** Marshy areas (**methanogens**)

(ii) Archaebacteria have different cell wall structure when compared with other bacteria. As a result, they are able to tolerate extreme conditions. Their cell membrane is constituted by branched chain lipids.

(iii) **Methanogens** are found in guts of many ruminant animals like cows and buffaloes. They are able to produce methane (biogas) from dung of such animals.

(iv) **Halophiles** lie in habitats having high salinity and high light intensity. They are able to live in high salt concentration because their intracellular salt concentration is equally high. Halophiles are aerobic heterotrophs which live in brine.

(v) Facultative or obligate anaerobes that chemoheterotrophically or facultative chemoautotrophically live in hot sulphur springs are similar areas are called **thermoacidophiles.**

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BACTERIA

Anton Van Leeuwenhoek (1676) discovered the bacteria in pond water and tartar scrapped from teeth and called them as animalcules. Much has been added to our knowledge about bacteria during last few decades. They have following **important characters :**

1. They are prokaryotic.

2. The flagella whenever present are made up of single strand.

3. Well organised nucleus, Golgi body, mitochondria are absent in the cells of bacteria.

4. Basically, they are unicellular.

5. Cell wall is made up of murein or peptidoglycan.

6. They are smallest of all the living organisms with a cellular organisation.

7. Cytoplasmic streaming and sap vacuoles are absent in bacterial cell. In some bacteria, gas vacuoles may be present.

8. Mostly bacteria are heterotrophic due to absence of chlorophyll. Some bacteria may be photoautotrophic and chemoautotrophic. Photo-autotrophic bacteria contain bacteriochlorophyll instead of true chlorophyll.

9. Major method of reproduction in bacteria is binary fission.

BLUE GREEN ALGAE (CYANOBACTERIA)

Habit and Habitat. Blue-green algae or Cyanobacteria or Cyanophyta are Gram negative and photosynthetic. The blue-green algae live virtually in all environments **that contain water**. The organisms range from tropics to plains and they occur in soil, fresh water and ocean. In lakes and in the ocean they form part of plankton. Some cyanobacteria live in the icy waters of glaciers others in hot springs where temperatures reach 85°C or more. Some blue-green algae live as symbionts with other organisms. For example, they often are the algal members of lichens.

Characters

1. Common forms are unicellular, colonial, filamentous or heterotrichous.

2. The cell wall possesses an outer sheath (outside) which is jelly like, slimy and mucilaginous.

3. The cell contents are divided into two regions, outer **chromatoplasm** having photosynthetic pigments and inner colourless **centroplasm.**

4. The cell wall is two layered. The inner wall is made up of peptidoglycan or mucopeptides built up from amino sugars (*e.g.* glucosamine) and amino acids (*e.g.* muramic, diaminopimelic).

5. Bacteria and blue-green algae lack mitochondria, true vacuoles and endoplasmic reticulum.

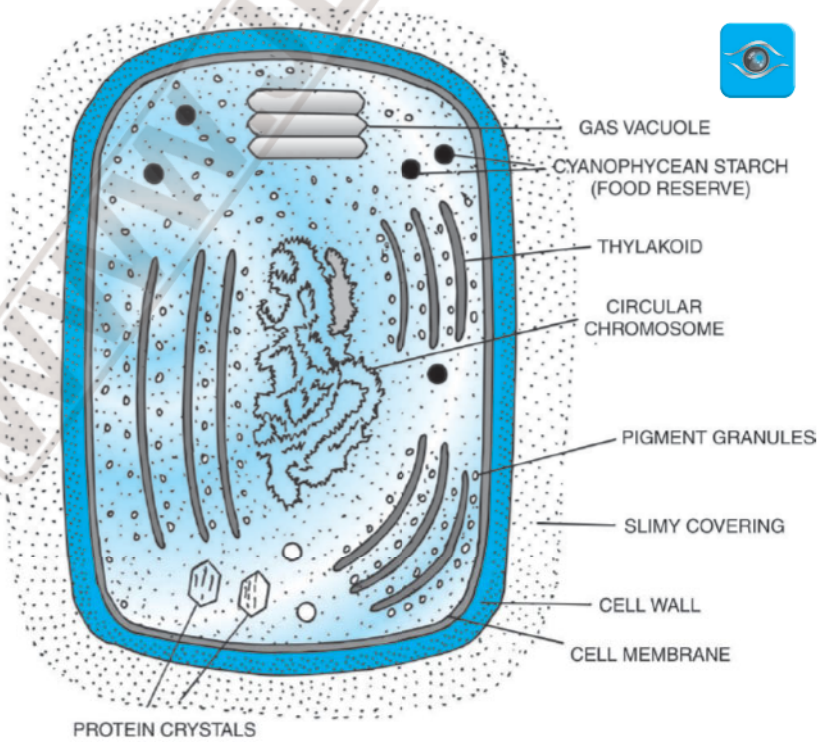

Fig. 6. A Cyanobacterial-cell.

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DID YOU KNOW?

- Lactic acid bacteria can go for anaerobic respiration or fermentation even in presence of oxygen. They are known as **aerotolerant an aerobes.**
- Certain forms of aerobic bacteria are able to respire aerobically even in absence of free oxygen by utilizing oxygen of oxidised salts like nitrates e.g. dinitrifying bacteria. They are called as **anaerotolerant aerobes.**
- *Coccobacillus* is cylindrical bacterium having length almost equal to breadth e.g. *Brucella*.

6. Sterols are absent in bacteria as well as cyanobacteria.

7. There is no membrane bounded chloroplast and photosynthetic lamellae or thylakoids are usually distributed in the peripheral cytoplasm (Fig. 6).

8. True nucleus is absent. Fine fibrils of DNA are either distributed throughout the cell or concentrated in the central part. Its chromosome resembles bacterial chromosome.

9. Well marked reproductive organs, sexual reproduction and motile reproductive bodies are absent in cyanobacteria.

10. Gas vacuoles are often present to regulate the buoyancy in water.

11. The colour ranges from green to deep purple often blue green. Thus the name blue green algae is misleading. These colours are produced by different proportions of several pigments like chlorophyll *a*, carotene, xanthophyll, blue **phycocyanin** and red **phycoerythrin.** The last two are tetrapyrrole derivatives occurring uniquely in the cyanobacteria.

12. Reserve food is in the form of cyanophycean (myxophycean) starch.

13. Flagella are absent in vegetative as well as reproductive phase.

KINGDOM PROTISTA

(Unicellular Eukaryotes)

Protists show the following characteristics :

1. Protists include solitary unicellular or colonial unicellular eukaryotic organisms which do not form tissues.

2. Simple multinucleate organisms or stages of life cycles occur in a number of groups.

3. The organisms possess nuclear membranes and mitochondria.

4. In many forms, plastids, (9 + 2 strand) flagella and other organelles are present.

5. The nutritive modes of these organisms include photosynthesis, absorption, ingestion and combination of these.

6. Their reproductive cycles typically include both asexual divisions of haploid forms and true sexual processes with karyogamy and meiosis.

7. The organisms move by flagella or by other means or are non-motile.

The organisms included in protista (*Protistos*—primary) represent diverse ways of life. Many are **photosynthetic autotrophs** *e.g.* unicellular coloured algae and diatoms. They are collectively known as **phytoplankton** or microscopic, floating photosynthetic organisms. Many of these bear cell wall and still several others have flagella.

Few other protistan organisms are predatory and feed on other protists. They are included in protozoa. Cell wall is absent in **protozoa** and they permit ingestion of particulate food—showing animal like **holozoic** type of mode of nutrition. Some protozoans are found in gut, digestive tract of all types of other animals.

Few help in decomposition of organic matter like otherwise indigestible cellulose found in cell walls of plants, as in termites and wood consuming cockroaches.

IMPORTANT GROUPS OF PROTISTA

1. Chrysophytes (diatoms and golden algae-desmids)

Diatoms, included in phylum **Chrysophyta** of algae are also known by the name **golden algae.** They have been grouped under two categories namely **pennate types** and **centric types.** Pennate types are bilaterally symmetrical and centric types are radially symmetrical and show the following characters :

1. Diatoms are microscopic, single celled forms. Cell is called as **frustule** or **shell.**

Table 3. Differences between Bacteria and Cyanobacteria (blue green algae).

S.No	Characters	Bacteria	Blue green algae
1.	**Size**	Comparatively smaller.	Comparatively larger.
2.	**Flagella**	May bear flagella.	Flagella always absent.
3.	**Nutrition**	May be autotrophic or heterotrophic.	Usually autotrophic.
4.	**Photosynthetic pigments**	Photosynthetic pigments are bacteriochlorophyll and chlorobium chlorophyll.	Photosynthetic pigment is chlorophyll-*a*.
5.	**Accessory pigments**	Absent	Accessory pigments like phycocyanin and phycoerythrin are present in dominating form.

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6.	**Hydrogen donor**	During photosynthesis, hydrogen donor is not water, as a result oxygen is not evolved. Thus photosynthesis is anoxygenic.	Hydrogen donor is water, oxygen is evolved. Process is oxygenic.
7.	**Reserve food**	Reserve food is glycogen.	Reserve food is cyanophycean starch.
8.	**Spore formation**	Spore formation is endogenous.	Spore formation is not endogenous.

2. They are present in both fresh and salt water and comprise an important food for the aquatic animals. However out of 5,500 species most are marine.

3. They lack flagella and float mainly due to light storage lipids present in them.

4. Diatoms have cell walls containing silica, constructed in two overlapping halves, which fit together like two parts of a soap box (pennate types) or pair of petridishes (centric types).

5. Due to their silica impregnations, the walls of diatoms are indestructible. As a result **diatomaceous earth** formation has occurred due to remains of cell walls of diatoms in the form of fossils.

6. Silica wall of diatoms is designed with fine ridges, lines, pores etc. These ornamentations are either radially symmetrical or bilaterally symmetrical on either side of the long axis of the cell. The outer wall is called epitheca and inner wall is called hypotheca.

7. Diatoms may exhibit slow gliding movements produced by streaming of cytoplasm through grooves on the surface of cell wall.

8. The cell wall is made up of two units hence the name diatom.

9. Due to various designs over the cell wall, they have been regarded as jewels of the plant kingdom (Fig. 7).

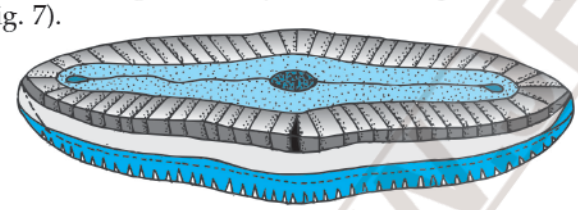

Fig. 7. A diagrammatic view of a typical diatom, highly magnified. The shells have characteristic fine lines and the upper and lower shells fit together like the part of a soap box.

2. dianoflagellates

They comprise the phylum **Pyrrophyta** of algae and show the following characters :

1. They are single celled, most of them are surrounded by a shell made up of thick interlocking plates.

2. They are motile with two flagella, one projecting from one end and the other running in a transverse groove.

3. Like diatoms they have fucoxanthin in addition to chlorophyll. They are autotrophic and photosynthetic (e.g. *Ceratium*). *Blastodinium* is a colourless parasite on animals.

4. The food reserve is in the form of oils and polysaccharides.

5. Most of the dinoflagellates are marine and important photosynthesizers in the ocean.

6. Occasionally members like *Gonyaulax* accumulate in large numbers in some parts of sea, colouring the water red and are responsible for **red tide.**

7. Some species of dinoflagellates are **poisonous** to vertebrates and when these accumulate, large number of fish in that region of ocean may be killed.

8. Some members are **phosphorescent** and make the sea glow in the dark.

9. Dinoflagellates are covered with cellulose cell walls which are divided into plates (Fig. 8). The plates give them armoured appearance.

10. Most of the 1000 species included are marine.

11. Method of reproduction is only asexual. Sexual reproduction is usually absent (exception–*Ceratium*).

12. Some species of dinoflagellates are taken as food by mussels. These mussels remain unharmed by dinoflagellates but if man eats these infected mussels, he may fall ill.

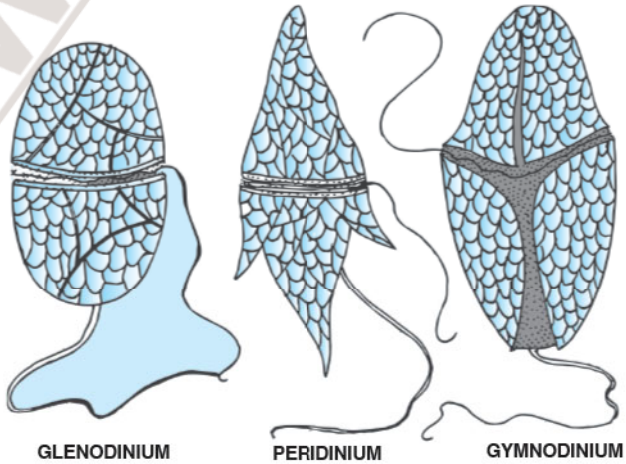

Fig. 8. Three species of dinoflagellates. Note the plates which enclose and encase the single celled body and the characteristic two flagella, one of which is located in the transverse groove.

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3. Euglenoids

Euglenoids show the following distinguishing characters :

1. Unicellular *Euglena* (Fig. 9) and its relatives have both **animal** and **plant** characteristics.

2. Euglenoids are more advanced than blue-green algae from evolutionary point of view, for they have a definite easily stained nucleus and the chlorophyll is not scattered in granules but is localized in chloroplasts as in higher plants. The nuclear envelope persists during division.

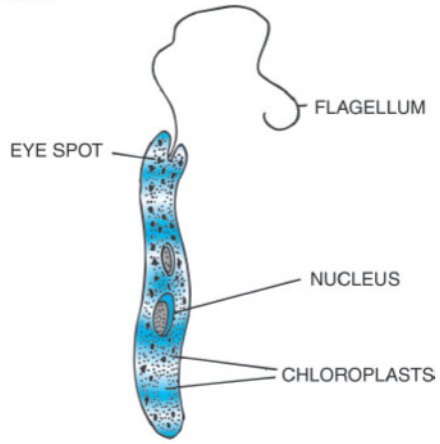

Fig. 9. *Euglena* is very much like protozoans but it bears chloroplast.

3. They are free living, found in fresh water ponds and ditches or in the damp soil. *Euglena* is more readily available protist for laboratory studies.

4. Euglenoids are characterised by absence of cell wall, but they do contain flexible **pellicle** made up of protein.

5. All the euglenoids have one or two flagella by means of which they can swim easily.

6. *Euglena* bears a flagellum inserted at the anterior end in a cavity.

7. They bear a red pigmented eye spot and a gullet near the base of the flagellum. The pigment in eye spot is **astaxanthin.**

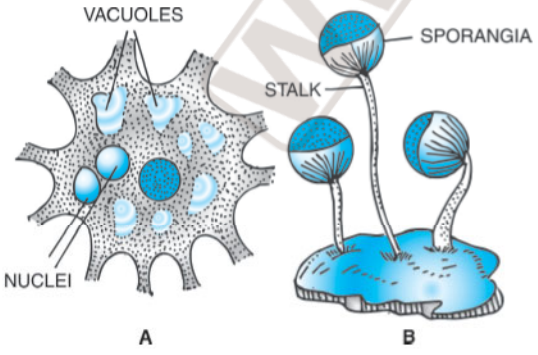

Fig. 10. Slime mould *Physarum*.
A. Plasmodium; **B.** Fruiting bodies.

8. Some euglenoids are green and holophytic (photoautotrophic) like other plants. Few are non-green and saprobic like fungi and bacteria. Some capture and ingest the organisms like animals (holotrophic). Green forms have saprobic mode in addition to holophytic (*i.e.* myxotrophic). Photosynthetic forms bear many, radiating chloroplasts. The chloroplasts contain pigments like chlorophyll *a*, chlorophyll *b* and xanthophyll. Holotrophic or phagotrophic nutrition is absent in *Euglena*. Euglenoids store carbohydrates in the form of **paramylum** chemically distinct from starch and glycogen.

9. Reproduction is usually asexual by cell division but sexual reproduction has been reported in one genus. Under favourable conditions, euglenoids reproduce by simple, longitudinal binary fission.

10. Flagellum disappears prior to division.

11. Most of the species produce **cyst** having thick stratified membranes with deep red colouration due to synthesis of haematochrome.

12. Besides cyst formation, many of non-flagellate cells may get embedded in a common gelatinous sheath resembling a palmella stage.

13. Few examples of euglenoid flagellates are : *Euglena, Paranema, Astasia, Trachelomonas.*

4. Slime Moulds

Slime moulds (500 sp.) (Fig. 10, 11) also known as slime fungi, constitute a peculiar group of organisms having several features which are animal like in their vegetative stages and plant like in reproductive stages. Many workers have studied them alongwith animals due to lack of cell wall, their amoeboid movement and feeding habit. Now, they are studied along with plants because of the presence of cellulosic cell wall on spores and zoospores, lack of chlorophyll like fungi, saprophytic nature and mode of reproduction like that of primitive fungi.

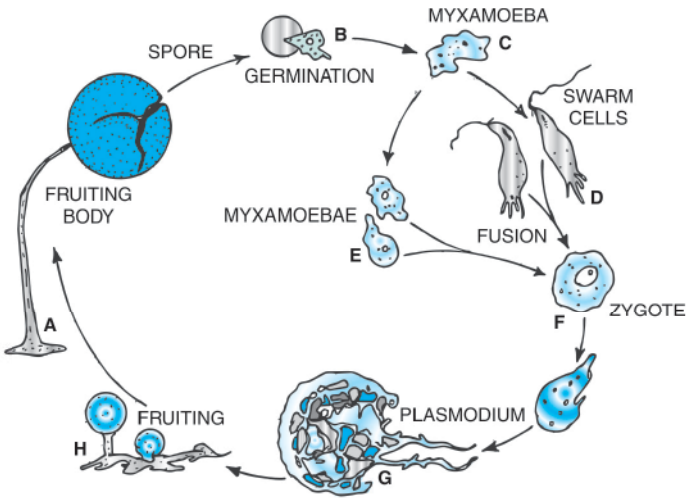

Fig. 11. Life cycle of Myxomycetes (slime moulds).

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Occurrence

The slime moulds are widely distributed, growing in damp and shady places. They may be found in the soil rich in humus, damp old planks of wood, rotting logs, decaying leaves etc. They prefer moisture and darkness or dim-light for normal growth, They move to drier and exposed habitats during reproductive phase. More than 100 species have been reported from India. The common genera are—*Physarum*, *Stemonitis*, *Comatricha*, *Trichia* etc.

General Features

1. The vegetative phase of the thallus is a free-living, naked, multinucleated mass of protoplasm called **Plasmodium.**

2. The plasmodium consists of diploid nuclei, lacks cell wall and secrets slime.

3. Chlorophyll is lacking, so these are generally **saprophytic,** rarely parasitic causing abnormal swellings upon the bodies of hosts.

4. The plasmodium shows amoeboid movement by producing pseudopodia.

5. They reproduce by means of spores produced in sporangia.

6. The spores have cellulosic cell wall and are produced through meiosis.

7. The slime molds are, generally, **holocarpic.**

8. The spores germinate to produce **myxamoebae** or biflagellated **swarm cells** behaving as gametes.

9. The swarm cells fuse in pairs showing **isogamous** type of sexual reproduction.

10. Slime moulds may be colourless or variously coloured like yellow, orange, brown, etc.

Somatic structure

The thallus consists of a slimy mass of protoplasm. It is naked (lacking cell wall) and multinucleated known as **plasmodium.** The size of the plasmodium may vary from microscopic to several centimeters in diameter according to the species. Due to the absence of cell wall, there is no definite shape. The plasmodium is surrounded by plasma membrane externally.

The plasmodium forms pseudopodia and shows amoeboid movements creeping over the substratum. It also grows within the substratum and in all directions, commonly towards the moisture and avoiding light as far as possible. It is slimy to touch and show variation in colour depending upon the species. The plasmodium lacks chlorophyll and engulfs solid particles of food and can absorb food material in solution also.

5. Protozoans

All protozoans are found as predators or parasites and are heterotrophic

Major groups of protozoans are :

A. ZOOFLAGELLATA (FLAGELLATED PROTOZOANS)

Characters. Zooflagellates are characterised by :

1. Habitat. Most of zooflagellates are endoparasitic and pathogenic and are spread by certain vectors e.g. *Trypanosoma*, *Leishmania*, *Giardia intestinalis*; *Trichomonas vaginalis* etc. Some are found as symbionts e.g. *Trichonympha.*

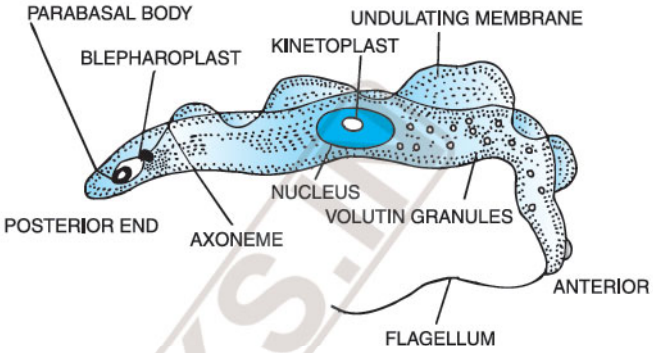

Fig. 12. *Trypanosoma gambiensis* (causes sleeping sickness).

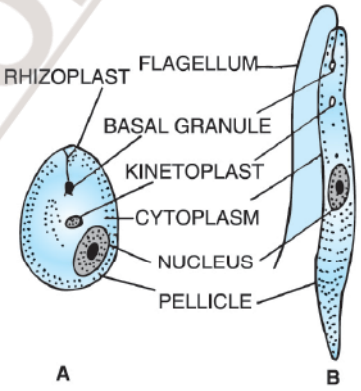

Fig. 13. *Leishmania donovani* **A** = Adult **B** = Young (causes **kala azar**).

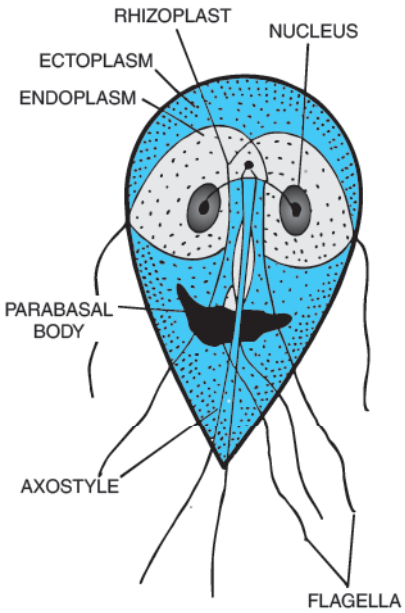

Fig. 14. *Giardia intestinalis* (causes **giardiasis**).

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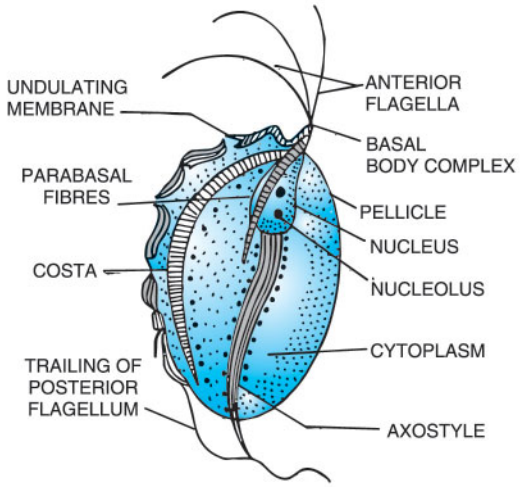

Fig. 15. *Trichomonas vaginalis* (cause of **leucorrhoea**).

2. Locomotion. Organelles of locomotion are one (e.g. *Trypanosoma*) or more flagella (e.g. eight flagella in *Giardia* and many flagella in *Trichonympha*).

3. Nutrition. Most of the zooflagellates are **heterotrophic** and **saprozoic** in their nutrition. Reserve food is glycogen.

4. Reproduction. These show only asexual reproduction by **longitudinal binary fission.** There is no sexual reproduction.

Example : *Trypanosoma gambiense.*

B. SARCODINA (AMOEBOID PROTOZOANS)

1. Habitat. Sarcodines are fresh-water (e.g. *Amoeba*) or marine (e.g. *Polystomella*) or endoparasitic and pathogenic (*Entamoeba histolytica*).

2. Locomotion. Locomotion occurs by temporary finger-like **pseudopodia** or **false feet** e.g. *Amoeba* (Fig. 16), *Entamoeba* etc. Pseudopodia are of following types:

(a) Lobopodia. These have broad and rounded ends e.g. *Amoeba*. These are formed of both ectoplasm and endoplasm.

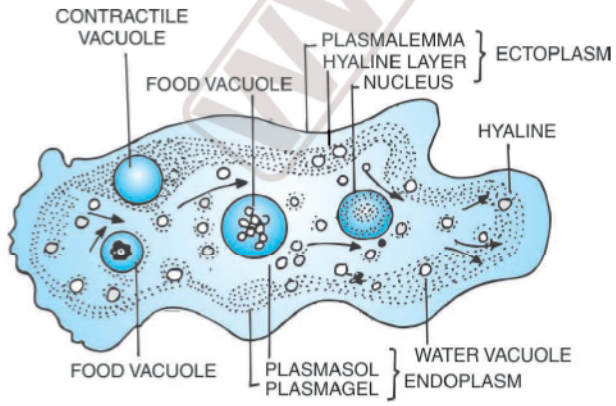

Fig. 16. *Amoeba proteus.*

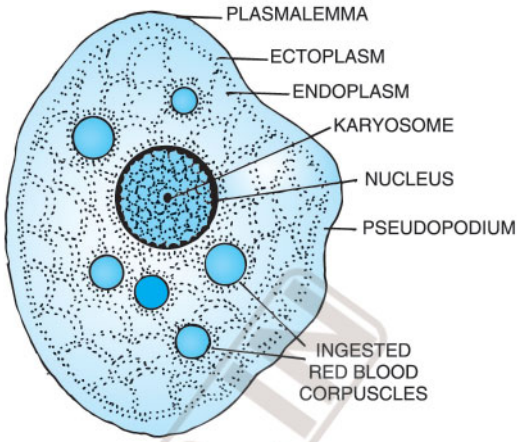

Fig. 17. *Entamoeba histolytica* (causes **amoebic dysentery**).

(b) Filopodia. These are filamentous pseudopodia with tapering ends and are formed of only ectoplasm e.g. *Euglypha.*

(c) Reticulopodia or **Rhizopodia.** These are filamentous and branched pseudopodia which form a network e.g. in **Foraminiferans** like *Elphidium, Globigerina* etc.

(d) Axopodia. These are straight and radiating pseudopodia each supported by axial filament e.g. in **Heliozoans** like *Actinophrys*. The pseudopodia give the appearance of sun-rays so heliozoans are commonly called **sun-animalcules.**

Pseudopodia are used both for locomotion and food-capturing.

3. Nutrition. These are **heterotrophic** and **holozoic** in their nutrition.

4. Reproduction. Asexual reproduction occurs by either binary fission or multiple fission e.g. *Amoeba*. Some forms show sexual reproduction by **syngamy** (e.g. *Pelomyxa, Actinophrys*).

5. These are either uninucleate (*Ameoba*) or multinucleate (*Pelomyxa*).

C. CILIATA (CILIATED PROTOZOANS)

Characters. It is the most advanced and diversified group of protozoa. These are though one-celled organisms but have specialized organelles to perform the different functions like mouth, digestive tract, anus, kidney, muscle and sense organs of multicellular organisms. These are characterised by :

1. Habitat. Many ciliates are fresh-water (e.g. *Paramecium*) while some ciliates are endoparasitic and pathogenic (e.g. *Balantidium*). Some ciliates are colonial or sedentary (suctorians).

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2. Locomotion. The organelles of locomotion are **cilia** which always beat in coordination. The cilia are generally distributed on whole body surface and also help in food collection. Some ciliates lose their cilia in adult stage e.g. *Podophyra*.

3. Nutrition. Ciliates are mostly **heterotrophic** and **holozoic** in their nutrition. These generally have **cytostome** (cell-mouth), a well-developed feeding apparatus and a **cytopyge** or **cytoproct** (cell-anus). Digestion is **intracellular** and occurs in a food-vacuole which takes a definite path (comparable to digestive tract) in the cytoplasm.

4. Reproduction. These show both **asexual** and **sexual reproduction.** Asexual reproduction occurs by **transverse binary fission** while sexual reproduction generally occurs by **conjugation** (comparable to cross-fertilization) or **autogamy** (comparable to self-fertilization). Some forms also show **endomixis** (comparable to parthenogenesis). Sexual reproduction especially conjugation is highly advantageous to the ciliates because it helps in :

(a) Recombination of genes producing variations.

(b) Replacement of abnormal macronucleus with depression stage by a normal macronucleus.

Other important characters of Phylum Ciliata

5. Nuclear Dimorphism. All the ciliate protozoans show **nuclear dimorphism. Micronucleus** is smaller and generative as controls reproduction while **macronucleus** is larger and vegetative in function.

6. Fresh-water ciliates e.g. *Paramecium* (Fig. 18), have contractile vacuole for **osmoregulation.**

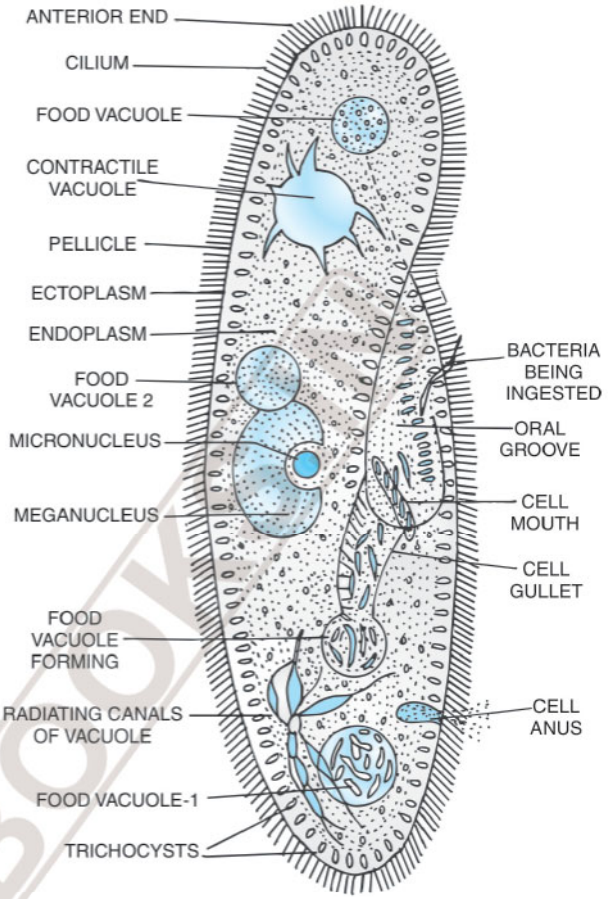

Fig. 18. *Paramecium.*

7. Pellicle. These are externally covered by flexible **pellicle** so have **definite shape.**

Table 4. Differences between four groups of Protistan Protozoans.

Characters	Zooflagellata	Sarcodina	Sporozoa	Ciliata
1. Habitat	Mostly **endoparasitic.** Some are **symbiotic** in their habitat.	Some are **fresh-water** while some are **endo-parasitic.**	All are **endoparasitic** and pathogenic.	These are **fresh-water** or **endoparasitic** in habitat.
2. Organs of food capturing and locomotion	One or more **flagella.**	Temporary finger or ray like false feet called **Pseudopodia.**	**Absent** due to parasitic mode of life.	Most of ciliates have **cilia** for locomotion and food-gathering.
3. Nutrition	Heterotrophic and **saprozoic.**	Heterotrophic and **holozic.**	Heterotrophic and **saprozoic**	Heterotrophic and **holozoic.**
4. Asexual reprodution	By **longitudinal binary fission.**	By **binary fission** or **multiple fission.**	By multiple fission called **sporogony** or **schizogony.**	By **transverse binary fission.**
5. Sexual reproduction	Absent	Some forms show **syngamy.**	By **gamogony.** These show alternation of generations.	By **conjugation** or **auto-gamy** or **endomixis.**
6. Nucleus	**Mononucleate** except ***Giardia*** (binucleate)	**Mononucleate** or multinucleate (e.g. *Pelomyxa*)	**Mononucleate.**	Always **binucleate.** Nuclei show **nuclear dimorphism.**
7. Trichocysts	Absent.	Absent.	Absent.	Present and are organelles of defence and anchorage.
8. Example	*Trypanosoma, Giardia, Leishmania, Trichomonas*	*Amoeba, Entamoeba Actinophrys, Pelomyxa*	*Plasmodium, Nosema.*	*Paramecium, Vorticella, Balantidium.*

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8. Trichocysts. These are fusiform-shaped ectoplasmic structures of ciliates which act as organelles of defence and anchorage.

D. SPOROZOA

Characters. These have simple body organisation due to their parasitic mode of life and are characterized by :

1. Habitat. All are **endoparasitic** and pathogenic.

2. Locomotion. The organelles of locomotion and food-capturing are **absent** due to parasitic life.

3. Nutrition. These are always **heterotrophic** and **saprozoic** in nutrition.

4. Reproduction. These generally show **alternation of generation** between asexual (multiple fission) and sexual (syngamy) generation. Life cycle always involves the formation of haploid cells called **sporozoites.** Life cycle shows alternation of generation and is **monogenetic** or **digenetic.**

Example : *Plasmodium* (Malarial parasite) (Fig. 19).

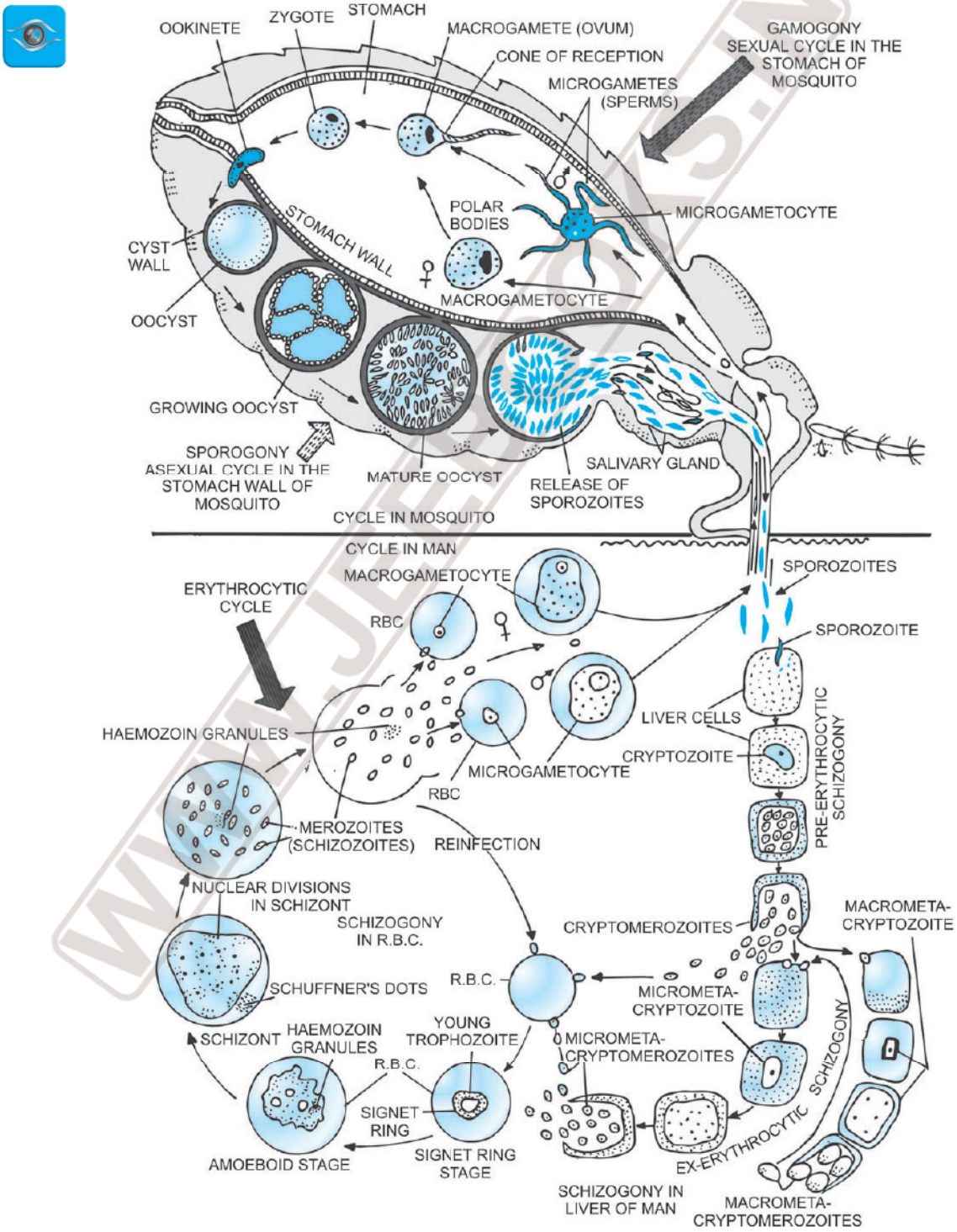

Fig. 19. Life cycle of *Plasmodium vivax.*

Table 5. Differences between Monera and Protista.

Characters	Monera	Protista
1. Nucleus	Prokaryotic	Eukaryotic
2. Cell size	Comparatively small (0.1 – 5 µm)	Comparatively large (10 – 100 µm)
3. Cell wall	Made up of peptidoglycan	Made up of cellulose
4. Flagella	If present, unistranded	It present, 11 stranded
5. Envelope system	Single	Double
6. Ribosomes	70S type	Cytoplasmic ribosomes : 80S Organelle ribosomes : 70S
7. Organelle	Membrane bound cell organelle absent	Membrane bound cell organelle present
8. Sap vacuole	Absent	Present
9. Cell division	Mitotic spindle absent, cell division is of amitosis type	Mitosis due to formation of spindle
10. Sexual reproduction	Absent	Present
11. Meiosis	Absent	Present

Table 6. Comparison between Plasmodium and Pseudoplasmodium.

Characters	Plasmodium	Pseudoplasmodium
1. Definition	Plasmodium is free living multinucleate amoeboid mass of protoplasm.	Pseudoplasmodium is an aggregation of *Amoeba* like cells (or plasmodia). Here identity of every cell is maintained.

Table 7. Differences between Flagella and Cilia.

Characters	Flagella	Cilia
1. Length	Long with length about 150 µm	Small with length 5–10 µm.
2. Number	Few, (1-4) per cell	Large (3000 - 14000) per cell.
3. Beating	Beat independently and exhibit undulatory motion.	Beat in coordination in succession.

ADDITIONAL USEFUL INFORMATIONS ABOUT PROTISTAN PROTOZOA FOR COMPETITIVE EXAMINATIONS

- *Basis of classification of Protistan Protozoans is* ***organs of locomotion.***
- ***Goldfuss :*** *Gave the term* ***Protozoa.*** *Protozoans are* ***unicellular protist animals.***
- ***ZOOFLAGELLATA :***
  - ***Trypanosoma gambinese :*** *Antelope is reservoir host. It was first reported by* ***Ford and Dutton*** *(1902) while its vector host tse-tse fly was reported by* ***Klein*** *(1909). It is a* ***polymorphic*** *protozoan and occurs in* ***four forms.***
  - ***T. rhodesiense :*** *Causes* ***East African*** *or* ***Rhodesian sleeping sickness.*** *Its vector is* ***Glossina morsitans.***
  - ***T. cruzi :*** *Causes* ***South American sleeping sickness*** *or* ***chagas disease.*** *Its vector is a blood sucking bug,* ***Panstrongylus megistus (Triatoma megista).***
  - ***Leishmania donovani :*** *Dogs and cats act as reservoir hosts. It was reported by* ***Leishman and Donovan.***
  - ***L. brasiliensis :*** *Causes* ***muco-cutaneus leishmaniasis (Espundia)*** *Vector host is* ***P. sergenti :***
  - ***L. tropica :*** *Causes* ***cutaneus leishmeiniasis*** *or* ***oriental sore.*** *Vector host is* ***P. intermedius.***
  - ***Giardia intestinalis :*** *It was reported by* ***Leeuwenhock*** *(1681) in his own faeces and was first pathogenic protozoan to be discovered. A* ***binucleate*** *flagellate.*
  - ***Trichomonas hominis :*** *In large intestine of man and causes diarrhoea.*
  - ***Opalina :*** *An* ***endocommensal*** *in the rectum of frogs, toads, etc. A multinucleate protozoan and undergoes* ***plasmotomy.***
- ***SARCODINA :***
  - ***Pseudopodia*** *may be* ***lobopodia*** *(with broad and rounded tips e.g. (Amoeba); or* ***filopodia*** *(with filamentous pseudopodia with tapering ends e.g. Euglypha); or* ***reticulopodia.*** *(branched pseudopodia forming network e.g. Elphidium);* or ***axopodia*** *(e.g. radiating pseudopodia with axoneme e.g. Actinophrys).*

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- ☞ ***Mastigamoeba :*** *Has both pseudopodia and flagellum so acts as* ***connecting link*** *between flagellates and sarcodines.*
- ☞ ***Amoeba proteus :***
  - — ***Rosenhof*** *(1755) : Discovered* ***Amoeba proteus.*** *Called it* ***little proteus.***
  - — *Externally covered by* ***plasma-membrane*** *and no pellicle.*
  - — ***Hyman*** *(1917) proposed* ***sol-gel theory*** *of pseudopodia formation. Supported by* ***Pantin*** *(1923) and* ***Mast*** *(1926).*
  - — ***Goldacre and Lorch*** *(1952) proposed molecular* ***folding-unfolding theory.***
  - — ***Sporulation*** *occurs in unencysted adult and produces 200 spores.*
- ☞ ***Entamoeba histolytica :*** *It was first discovered by* ***Lamble*** *but its pathogenic nature was reported by* ***Losch*** *(1875).*
- ☞ ***E. gingivalis :*** *Commonly called* ***mouth amoeba.*** *It is found in tartar of teeth and aggravates* ***pyorrhoea.***
- ☞ ***E. coli :*** *Found as an* ***endocommensal*** *in the colon of about 50% population. It is* ***non-pathogenic.***
- ☞ ***Pelomyxa :*** *Also called* ***giant amoeba.*** *It is* ***multinucleate*** *and has 100-1000 monomorphic nuclei.*
- ☞ ***Heliozoans :*** *(called* ***sun animalcules)*** *have axopodia and are shelled protozoans e.g. Actinophrys*
- ☞ ***Radiolarians*** *and* ***Foraminiferans*** *are giant sarcodines.*
- ☞ ***Egyptian pyramids*** *are formed of* ***Foraminiferan ooze.*** *Limmulittie limes of Eocene period are also formed of foraminiferan ooze.*

- ● *SPOROZOA :*
  - ☞ ***Plasmodium***
    - — *Term malaria was coined by* ***Macculoch*** *and means* ***"bad air".***
    - — ***Laveran*** *(1880) : Discovered malarial parasite (amoeboid stage) in RBCs of man.*
    - — ***Ronald Ross*** *(1897) : Reported malaria-mosquito relationship.*
    - — ***Grassi (1900) :*** *Described the life cycle of* ***Plasmodium*** *in the stomach of female* ***Anopheles.***
    - — ***P.C. Granham :*** *Detailed* ***monograph*** *of malarial parasite.*
    - — ***Cerebral malaria*** *caused by* ***P. falciparum*** *is most serious type of malaria as it damages brain.*
    - — *20th August is called* ***malaria day,*** *white 29th August is called* ***mosquito day.***
    - — ***NMEP (National Malaria Eradication Programme)*** *was started in 1953.*
    - — ***Haemozoin :*** *A toxic pigment formed by proteolysis of Hb of RBCs.*
  - ☞ ***Nosema bombycis :*** *Causes* ***pebrine disease*** *in the silk worms so reduces the silk production. It is inherited through the eggs.*
- ● *CILIATA :*
  - ☞ *Coordinated ciliary beating may be* ***metachronous*** *(when cilia of transverse rows beat simultaneously) or* ***synchronous*** *(when cilia of longitudinal rows beat simultaneously).*
  - ☞ ***Nuclear dimorphism :*** *Presence of two morphologically and physiologically different nuclei e.g. in ciliates.*
  - ☞ ***Trichocysts :*** *Reported by* ***Ellis. Hill*** *(1752) : Discovered* ***Paramecium.***
  - ☞ ***T.H. Sonneborn*** *(1917) : Reported that* ***Paramecium caudatum*** *has 16 syngens (varieties showing conjugation), while* ***P. aurelia*** *has 14 syngens. He also reported the* ***cytoplasmic inheritance of Kappa particles in Paramecium.***
  - ☞ ***P. bursaria*** *(green spp.) shows symbiosis with green alga,* ***Zoochlorella.***
  - ☞ ***Depression or senile decay :*** *A stage at which meganucleus becomes inactive and vegetative functions are stopped.*
  - ☞ ***Vorticella*** *(Bell animalcule) : An* ***epizoic*** *and* ***colonial*** *protozoan. It was first protozoan to be discovered.*

KINGDOM FUNGI

(Multicellular decomposers)

The distinctive characters of **Fungi** are :

(a) They are heterotrophic due to absence of chlorophyll.

(b) They become either parasites or saprophytes **(heterotrophs).**

(c) Thallus is made up of colourless filamentous structure called hyphae. The hyphae with branches and sub-branches form complex network called **mycelium.**

(d) Food material is stored in the form of glycogen and oil globules.

(e) Cell wall is made up of fungus cellulose.

(f) The nuclei are eukaryotic in nature.

(g) Gradual and progressive reduction of sexuality is present.

Along with some heterotrophic bacteria they are major **decomposers**. They are required for recycling of inorganic resources in the biosphere. Like some of the bacteria, some fungi also produce **diseases**. Especially important are the fungal diseases of plants, for fungi are more harmful to plants than bacteria are to human beings. Branch of biology which deals with the study of fungi is called **mycology.** The study of diseases caused in plants are included in **plant pathology.**

FUNGAL STRUCTURE AND NATURE OF GROWTH

The basic unit of the fungus is a **hypha**, a tubular often branched filament. Numerous hyphae are usually

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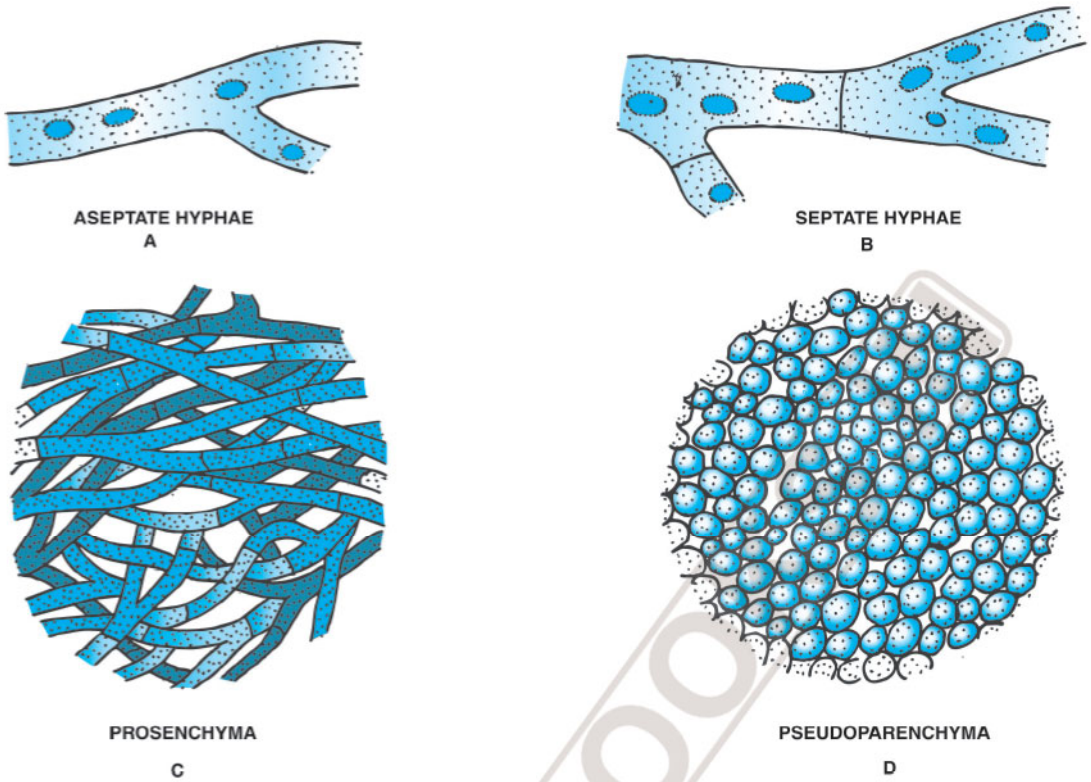

Fig. 20. Various types of fungal hyphae.

intermeshed as an irregular network, so called **mycelium**. Fungi extract energy from their environment by the process of **extracellular digestion** and absorption of the digested material in the form of solution. Since they lack chlorophyll and other photosynthetic pigments, they are incapable of carrying on photosynthesis, hence they do not require light for growth and metabolism. Some grow as **parasites** on all types of plants from simple algae to most advanced flowering plants. Some live on dead organic matter like dung, bread, jams etc. as **saprophytes**. Some live symbiotically with algae as **lichens**. Some of them are entirely subterranean (tuffles), others are aquatic (*Saprolegnia*). In septate hyphae, there usually occurs a central pore in septum through which protoplasmic connections are made between adjacent cells.

A body which consists of single cell and is completely converted into a reproductive structure is known as **holocarpic** but if only a part of the thallus is used up in the formation of reproductive structure, it is called **eucarpic**.

CELL AND TISSUE STRUCTURE

When the mycelium gets organised into loosely or compactly woven tissue like structure is called **plectenchyma. Prosenchyma** is the mycelium in which hyphae are loosely interwoven and lie more or less parallel to each other (Fig. 20 C). **Pseudoparenchyma** is the mycelium in which the hyphae are very loosely packed, so lose their identity completely and appear as isodiametric cells giving the appearance of parenchyma cells in higher plants. The protoplasm in a hypha may be continuous *i.e.* without any cross walls of septa (**aseptate**) (Fig. 20 A) or it may be interrupted by cross wall *i.e.* (**septate**) (Fig. 20 B).

The hyphal wall is made up of fungus cellulose in which cellulose is impregnated with chitin and contains nitrogen in addition to carbon and hydrogen.

The cell wall encloses the **protoplast.** In *Rhizopus* the protoplast is non-septate acellular or coenocytic in the actively growing condition, septa however may appear in old hyphae. The protoplast is covered by a thin semipermeable **plasma membrane**. The **cytoplasm**

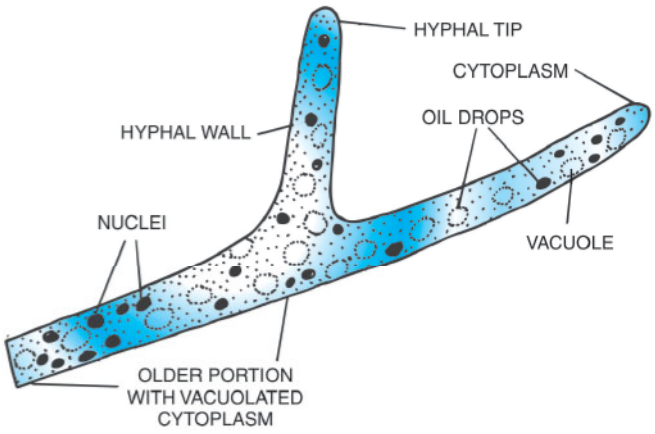

Fig. 21. Structure of aseptate, multinucleate (coenocytic) hypha of *Rhizopus*.

appears granular and contains many minute **nuclei** scattered in the peripheral layer. The nuclei are very small and inconspicuous. The cytoplasm contains many small **vacuoles** filled with cell-sap or a number of small gas filled vacuoles. The vacuoles are small, few or absent in the actively growing tips of the mycelium. The hypha also may be seen to have **mitochondria, dictyosomes** (Golgi body), **ribosomes, endoplasmic reticulum, oil drops** and **glycogen granules** etc. under electron microscope.

REPRODUCTION

The fungi reproduce by all the three methods—vegetative, asexual and sexual.

Vegetative reproduction. It is affected in various ways :

(i) Fragmentation. The hyphae of fungus break into small pieces and each piece may later grow into new mycelium.

(ii) Fission. It is common in yeasts etc. The cell divides into daughter cells which separate by constriction or transverse walls.

(iii) Budding. In this case daughter bud appears from parent cell. After getting the normal size bud breaks off. When the buds fail to separate, after repeated budding from **pseudomycelium**.

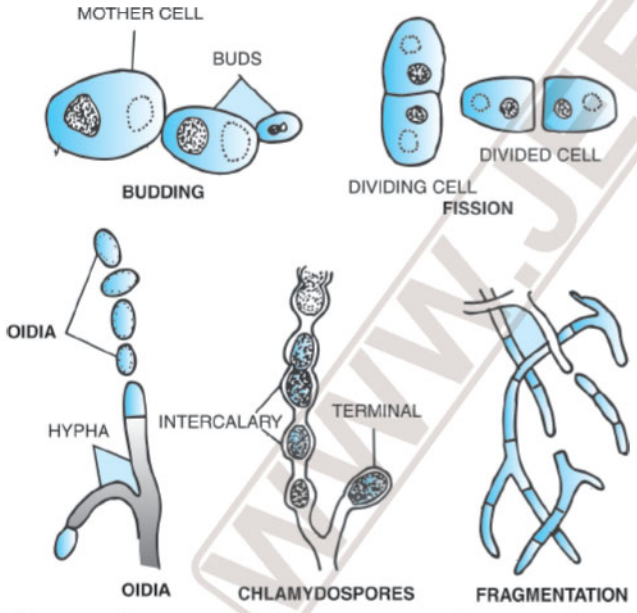

Fig. 22. Different types of vegetative reproduction in fungi.

(iv) Oidia. Oidia are rounded or oval structures having thin walls. The hyphae undergo segmentation and produce yeast like cells called oidia. Each oidium on germination produces new mycelium.

(v) Chlamydospores. Some fungi produce chlamydospores which are thick walled resting cells. They are intercalary in position. They are capable of forming a new plant on approach of favourable conditions.

(vi) Gemmae. They resemble chlamydospores in structure but not very durable and thick walled.

ASEXUAL REPRODUCTION

(i) Spore formation. The spores in fungi vary in shape. Spores are usually unicellular, thin walled, spherical and diameter ranging from 5—50μ. They may be hyaline or coloured. Several types of spores are reported in fungi *e.g.* zoospores, sporangiospores, uredospores, teleutospores, pycniospores etc. Sometimes the spores may be multicellular also. Sometimes the spores are produced endogenously in special sac-like asexual reproductive bodies called sporangia. Spores in such cases are called sporangiospores. Zoospores are uniflagellate or biflagellate structures.

(ii) Conidia formation. The detachable sporangia are often called conidia. Hyphae bearing conidia are called conidiophores. The conidiophores in groups may form structures like **coremia, acervuli, synnemata** etc. The conidia may behave as sporangia by developing motile zoospores. When the environment is dry, conidia germinate directly.

SEXUAL REPRODUCTION

Fungi may be dioecious or unisexual. Some are monoecious or bisexual. Former are **heterothallic** and latter are **homothallic**. The gametes are formed within **gametangium**. All the three types of sexual reproduction is present in fungi :

(a) Isogamy. Fusing gametes are exactly alike in appearance and functions.

(b) Anisogamy. Fusion of dissimilar gametes is called anisogamy. In anisogamous forms both fusing male and female gametes are usually motile.

(c) Oogamy. Fusion of male (micro) gamete (small, flagellated and active) with female (mega) gamete (large, non-motile and passive) is called oogamy.

Sometimes sexual reproduction occurs between two gametangia. Such fusion is called **conjugation** in contrast to gametic fusion. When gametangia can be differentiated, they are called **antheridium** and **oogonium** representing male and female sex organs respectively. In higher fungi somatic hyphae may fuse to show **somatogamy**. Fertilization involves two steps called **plasmogamy** and **karyogamy**. Plasmogamy is the fusion of cytoplasm and karyogamy is the fusion of nuclei.

When nuclei lie side by side, they represent **dikaryon**. Sexually fusion gametes result in the formation of diploid oospores or **zygospores**. In **fungi imperfectii** or deuteromycetes, sexual reproduction is absent. Meiosis occurs in zygospores to produce haploid spores. These spores are **genetically different** and are with new combination of characters due to crossing over in meiosis.

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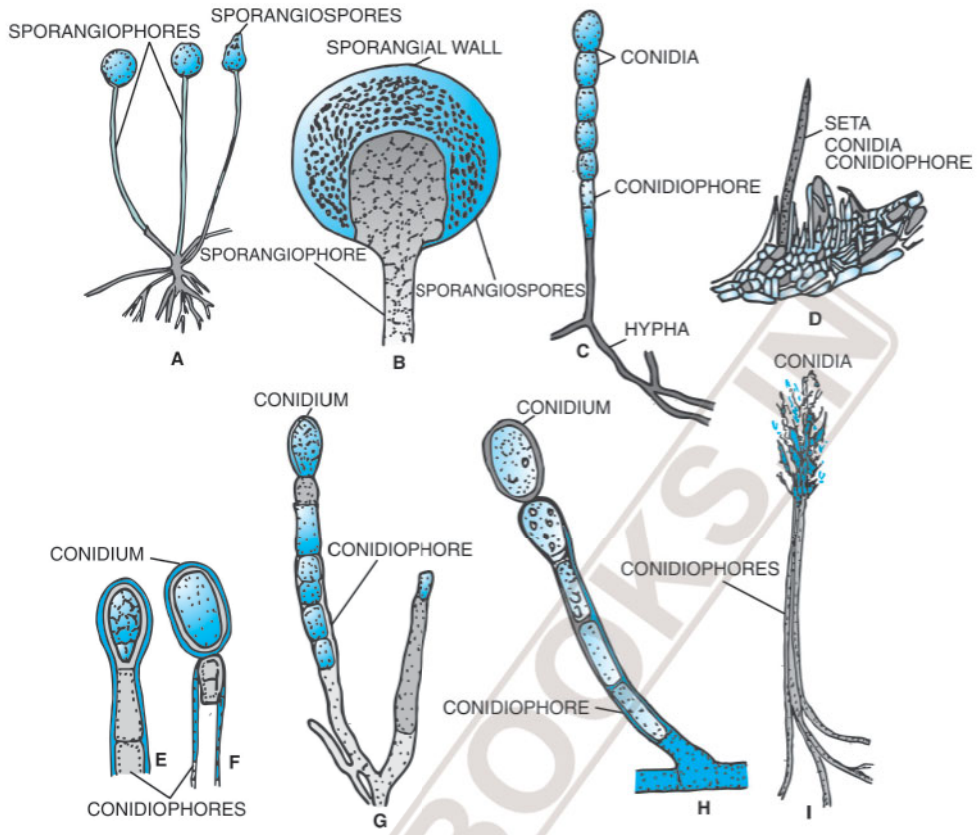

Fig. 23. Types of conidia and conidiophores, **A :** Sporangia and sporangiophores; **B :** Sporangiospores in a sporangium; **C :** Conidia arising from a conidiophore; **D :** Acervuli having setae and conidia; **E-H :** Development of an endoconidium from a conidiophore; **I :** Synnemata.

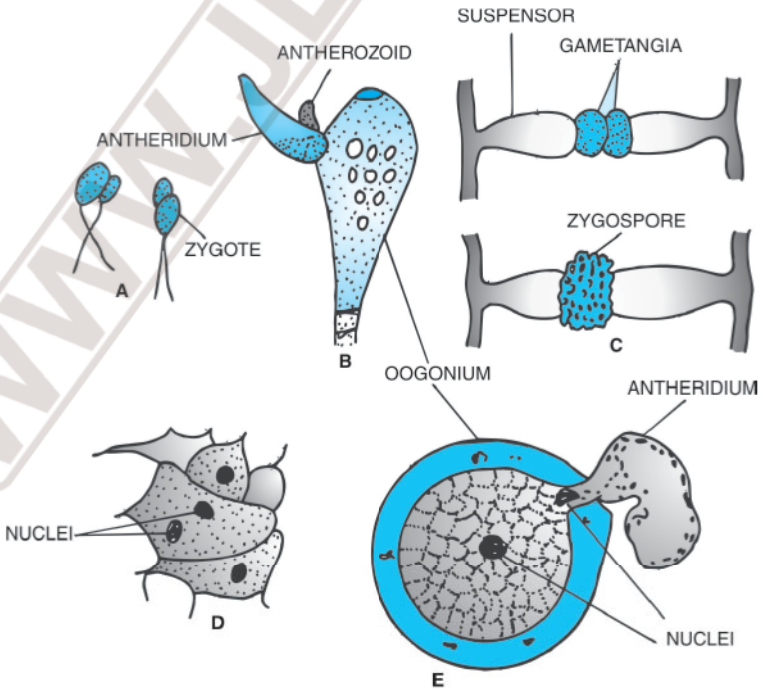

Fig. 24. Various aspects of fungal body, sexual structure **A:** Anisogametes on left, bicillate zygote on right **B:** Male and female gametangia, **C:** Isogametangia, **D:** Somatogamy, **E:** Differentiated gametangia.

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Eumycetes (True fungi)

- Non-septate mycelium (Lower fungi) **Phycomycetes**
  - **Mastigomycetes** (Flagellate members)
  - **Zygomycetes** (Non-flagellate members)
- Septate mycelium (Higher fungi)
  - **Ascomycetes**
  - **Basidiomycetes**
  - **Deuteromycetes**

FUNGUS CLASSIFICATION

Fungi has been variously classified by different authors depending upon the criteria they have used for the purpose. However, there is more or less agreement to classify true fungi into four different classes as given above :

Because in fungi structure of mycelium does not exhibit much variation, following criteria are considered mainly for classification :

(a) Morphology of reproductive structures.

(b) Physiology and biochemistry of various fungal members.

PHYCOMYCETES (ALGAL–FUNGI)

This group is characterised by the following characters :

1. Phycomycetes are called algal-fungi because of aquatic habitat and form of thallus. They are also found on decaying wood in moist damp places or on plants as obligate parasites.

2. Hyphae are multinucleate and aseptate **(coenocytic).**

3. Asexual reproduction takes place by motile zoospore formation or non-motile aplanospores.

4. Gametes may be similar morphologically **(isogamous)** or dissimilar **(anisogamous** or oogamous).

Examples : *Rhizopus*, *Mucor*, *Albugo* and *Phytophthora.*

ASCOMYCETES—THE SAC FUNGI

1. The largest class of fungi ascomycetes more than 35,000 species are included.

2. In ascomycetes, the spores are produced in sac-shaped structures called **asci**.

3. Each ascus bears 4-8 ascospores.

4. Ascomycetes includes yeast, powdery mildews, moulds, etc.

5. In some fungi imperfectii discovery of sexual stages have led to their inclusion in ascomycetes.

6. The ascomycetes may be unicellular as in yeasts, many celled filaments as mycelia as in powdery mildews or as thickened and fleshy as in tuffles.

7. Reproduction is accomplished asexually by **budding** (yeasts) or by spores called **conidia** that develop in sequence at the tips of certain hyphae.

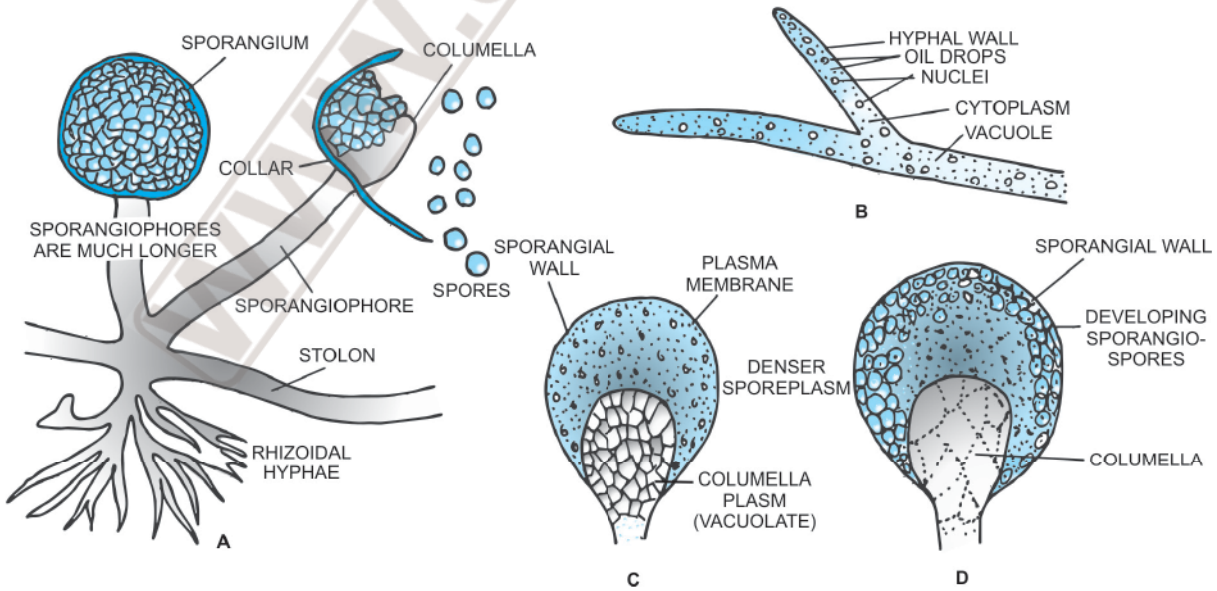

Fig. 25. *Rhizopus* **A.** Mycelium **B.** Hypha showing structure **C.** and **D.** Two developmental stages of sporangium.

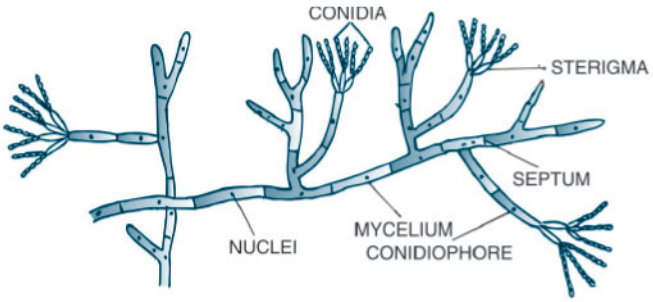

Fig. 26. *Penicillium* showing mycelium with conidiophores.

8. Sometimes conidiophores bearing conidia are organised into fruiting bodies of various kinds like **pycnidia, acervuli** etc.

9. Sexual reproduction in ascomycetes may occur by hologamy, gametangial contact, spermatisation and somatogamy.

10. Hologamy takes place in yeasts. Haploid cells directly act as gametes.

11. In some fungi like *Penicillium* male sex organs are differentiated into **antheridia** and female sex organs are called **ascogonia**. Each ascogonium is situated on one or two small basal cells called stalk cells and apex forms elongated **trichogyne**. Only plasmogamy occurs in the beginning as a result male and female nuclei lie in pairs to form **dikaryons.**

12. In **spermatisation** some ascomycetes bear minute spore-like **spermatia** on spermatophores. And they are transferred to ascogonial hyphae. Few show the tendency for the antheridium to become functionless and pairing occurs between the nuclei of ascogonium itself thus representing **autogamy**.

13. In somatogamy vegetative hyphae of opposite strain fuse.

14. Pairs in the ascogonium undergo conjugate divisions and ascogonium forms, hyphal outgrowths called **ascogenous hyphae**.

15. The terminal cell of each ascogenous hypha bend

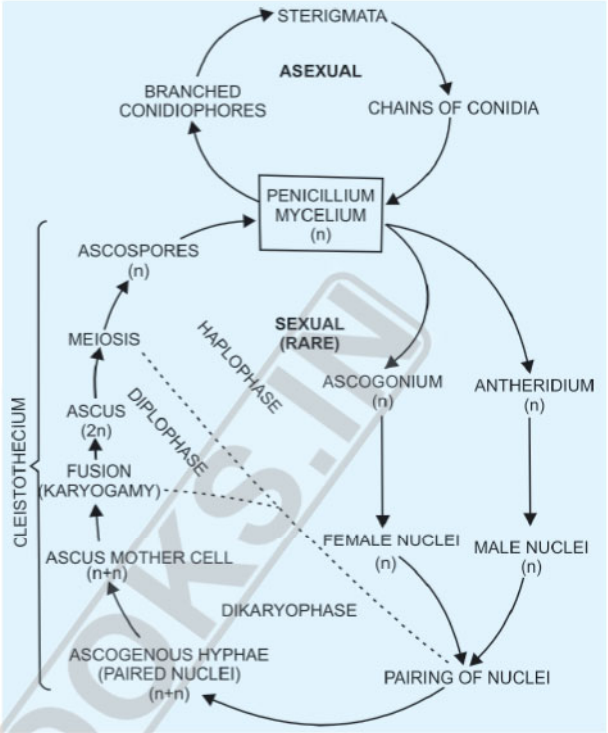

Fig. 27. Graphical life cycle of *Penicillium*.

to form **crozier** or **hook**. After division in the terminal cell three cells are delimited—the **terminal cell** containing single nucleus, the **subterminal** or penultimate cell containing two nuclei and the antepenultimate cell containing single nucleus.

16. Fusion occurs in **penultimate** cell now called ascus mother cell.

17. Diploid nucleus in ascus mother cell undergoes meiosis to form 4 nuclei followed by mitosis to constitute 8 haploid ascospores in newly developed ascus.

18. While the ascus development is going on, the mycelia surrounding the sexual structures grow up properly to cover the ascogenous hyphae, asci etc. The fruiting body or **ascocarp** thus formed may be of **Cleisothecium, Perithecium, Hysterothecium** and **Apothecium** type (Fig. 28).

19. Under favourable conditions each ascospore germinates to give rise to new hypha.

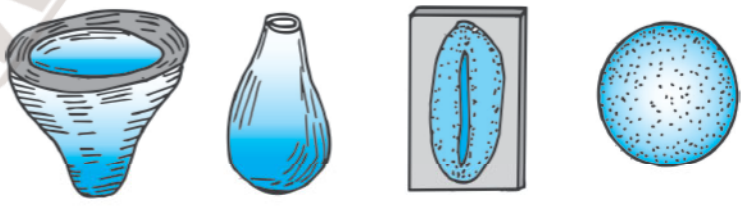

Fig. 28. Diagrammatic representation of various types of ascocarps in surface view.
A. Apothecium; **B.** Perithecium; **C.** Hysterothecium; **D.** Cleistothecium (closed).

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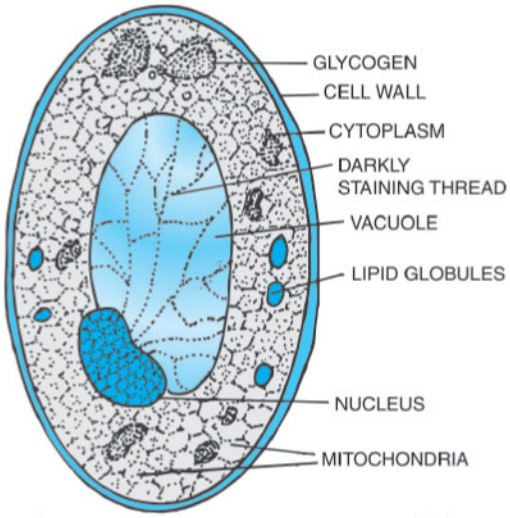

Fig. 29. *Saccharomyces cerevisiae.* A cell showing structure.

Fig. 30. Yeast : **A.** Budding; **B.** Fission.

BASIDIOMYCETES—THE CLUB FUNGI

Mushrooms, puff balls, toad stools, bracket fungi, rusts and smuts are included in basidiomycetes which comprises more than 25,000 species. They derive their name from the fact that they reproduce asexually by **basidium**. Each basidium is an enlarged, club-shaped, hyphal cell at the tip of which develop four **basidiospores**. Basidiospores develop outside the basidium. The basidiospores are released and develop new mycelia. No motile cells are formed at any stage of the life cycle of basidiomycetes. The somatic phase consists of a well developed, **septate**, filamentous mycelium. **Primary mycelium** is formed due to germination of haploid spore. It is soon converted into secondary or **dikaryotic** mycelium. The **clamp connections** on the dikaryotic hyphae are of universal occurrence. The sex organs are lacking. The sexual process is represented by plasmogamy and karyogamy. Basidiocarps of basidiomycetes are comparable to ascocarps of ascomycetes but they are not homologous.

Economic importance of basidiomycetes

1. Some of basidiomycetes are causative agents of most destructive diseases of our crops. To this category belong rusts (*Puccinia*) and smuts (*Ustilago*).

2. Few higher members of basidiomycetes such as pore **fungi** are wood rotters.

3. They are among best decomposers of wood. They decompose cellulose and lignin (mechanically strong) and may be resistant to other fungi including bacteria.

4. Mushrooms are of great economic value as food.

5. The toad stools are poisonous. Some as *Amantia* are fatally poisonous.

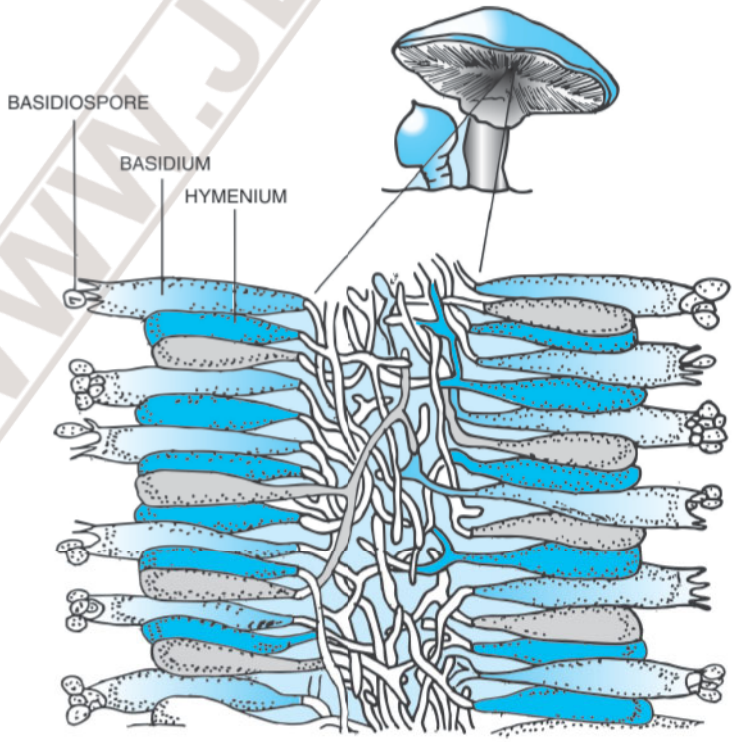

Fig. 31. Section of a gill from the underside of a mushroom cap to show the basidia and their basidiospores.

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Table 8. Differences between Ascocarp and Basidiocarp.

Characters	Ascocarp	Basidiocarp
1. Class	Found in ascomycetes	Found in basidiomycetes
2. Construction	Simple	Elaborate
3. Spore bearing structures	Asci	Basidia
4. Septa	Ascus usually aseptate	Basidium may be septate or aseptate
5. Location of spores	Endogenous	Exogenous
6. Number of spores	Eight	Four

Table 9. Differences between Ascus and Basidium.

Characters	Ascus	Basidium
1. Class	Meiospores forming structure in ascomycetes.	Meiospores forming structure in basidiomycetes.
2. Number of spores	Eight	Four
3. Location of spores	Endogenous in ascus	Exogenous on basidium
4. Dispersal	Rarely thrown out.	Thrown out by droplet method.

6. Few basidiomycetes produce hallucinogenic chemicals.

7. Many members form ectotrophic mycorrhizal associations with roots of forest trees. These associations are mutually beneficial.

8. The young fleshy sporophores of many species of puff balls are edible.

9. ***Clavatia***, a basidiomycete is said to be containing an anticancer substance clavicin.

10. Some mushrooms are poisonous like *Amanita.*

DEUTEROMYCETES—THE FUNGI IMPERFECTII

1. Sexual reproduction is absent.

2. They have members belonging to both ascomycetes and basidiomycetes.

3. They reproduce only by asexual spores i.e. **conidia** formation.

4. Hyphae are branched and septate.

5. Mode of nutrition is parasitic or saprophytic. Many act as decomposers of litter, thus helping in mineral cycling.

Examples : *Alternaria, Colletotrichum, Trichoderma Arthrobotrys* is an example of predatory fungus. This feeds on living worms (nematodes) and also called as **nematophagus** fungus.

KINGDOM PLANTAE

(Multicellular producers)

Kingdom plantae includes plants with following characteristics :

1. Multicellular organisms with walled and frequently vacuolate eukaryotic cells.

2. They contain photosynthetic pigments in plastids.

3. Principal mode of nutrition is photosynthesis but number of plants have become absorptive.

4. Primarily non-motile, living anchored to a substrate.

5. Structural differentiation leading towards organs of photosynthesis, anchorage and support and in higher forms towards specialised photosynthetic, vascular and covering tissues.

6. Reproduction is primarily sexual.

7. Haploid generation is progressively reduced in higher members of kingdom.

Examples are complex red, brown and green algae, mosses, ferns and seed plants with or without flowers.

KINGDOM ANIMALIA

(Multicellular consumers)

Organisms included in Kingdom Animalia show the following diagnostic characters :

1. They are multicellular organisms.

2. They bear eukaryotic cells and lack stiff cell walls.

3. They are devoid of plastids and photosynthetic pigments.

4. Nutrition is primarily ingestive with digestion in an internal cavity, but some forms are absorptive and number of groups lack an internal digestive cavity.

5. Level of organization and tissue differentiation in higher forms far exceeding that of other kingdoms, with evolution of sensory neuromotor systems or motility of organisms (or in sessile forms of its parts) based on contractile fibrils.

6. They have developed the cells with an ability to contract (muscle cells) or transmit impulses (nerve cells).

7. Reproduction is mainly sexual.

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8. Haploid stage other than gametes almost lacking above lowest phyla.

These holozoic eukaryotes are also called **Metazoa**. Kingdom Plantae and Animalia are both believed to have evolved from ancient protists, independently and at different times. Both groups are exclusively multicellular and their structural complexity reaches the level of complicated organs and organ systems. Kingdom plantae is photosynthetic and without locomotion. Metazoa are exclusively non-photosynthetic and largely capable of locomotion hence unmistakably animals.

Lot of diversity has been reported in this kingdom. More than million species have been identified and named belonging to this kingdom. Animals are **consumers**, while green plants are **producers**. They constitute links in various food chains and complex food webs through which a part of matter and energy flows from the producer to decomposer.

ADVANTAGES OF FIVE-KINGDOM CLASSIFICATION

1. Better relationship. It represents the better relationships in regard to both levels of organization and nutritive modes affecting kinds of organizaiton than the two-kingdom and Copeland systems of classification.

2. Better placement. The red and brown algae and the fungi may seem better placed, the former as the higher plants of the sea and the latter as the third major evolutionary direction among higher organisms.

3. Coherent system. This system is better in coherence and definable characters of kingdoms as units of classification.

4. Placement of *Euglena*. Unicellular eukaryotes like *Euglena* had earlier was included both in plants and animals. By grouping all unicellular eukaryotes in kingdom Protista, this anomaly has been removed.

5. Justification. By including prokaryotes like Bacteria and Cyanobacteria in kingdom Monera, justification has been made, because both differ from all other organisms in their morphological and physiological organisation.

6. Evolutionary trend. Five kingdom system of classification succeeds in indicating the gradual evolution of early organisms into plants and animals to a good extent.

7. Separation of kingdom Fungi. Fungi bear its own biochemical, physiological and structural organisation. This separation of kingdom fungi from plants was long overdue.

DISADVANTAGE OF FIVE-KINGDOM CLASSIFICATION

1. The distinction of the unicellular virus, the multicellular and multinucleate conditions becomes the line of division and difficulty.

2. The slime moulds cross the distinction of kingdoms in both nutrition and organization and offer free choice as fungi, protists or very peculiar animals.

3. The three higher kingdoms are polyphyletic.

4. Even with the multicellular algae and higher fungi excluded, the protista is a group of diverse organisms of divergent directions of evolution.

VIRUSES, VIRIODS AND BACTERIOPHAGES

The name 'virus' means venoum or poisonous fluid. Study of viruses is called **virology.** Viruses cause diseases like mumps, small pox, herpes, influenza and AIDS etc. in humans. Plant diseases like mosaic, leaf rolling and curling, yellowing and vein clearing, dwarfing, stunted growth etc. may also be viral.

Viruses and bacteriophages are much smaller than bacteria and indeed hardly larger than very large molecules of proteins and nucleic acids. They are too small to be seen with light microscope. They are much smaller than bacteria. They resist classification as plants or animals. In one sense the viruses are not living organisms but large nucleoprotein particles which enter specific kind of plant or animal or bacteria and multiply to form new virus particles. Bacteriophages are also viruses which parasitize bacteria (*phage*— eater). When viruses are outside the host cell, they are metabolically inert; in fact some viruses have been crystallized. They reproduce using the metabolic machinery of the host cell, and infect chemically. They are made up of one of the nucleic acids DNA or RNA (never both) and protein only. Genetic material DNA or RNA is enclosed within a protective coat of protein. So, the viruses show many of the properties of living organisms. Among these is the property of replication. Viruses are not as complex as cells, if for no other reason then the fact that they have none of the enzymes found in cells. Because of this, we place the virus just below the level of cellular organisation.

About viruses many questions come to our mind.

1. Do they represent the starting point of life in the evolution of living beings?

2. Are they highly evolved super parasites?

3. Have they been derived from some more complex organisms, such as bacteria, which have become greatly reduced in structure?

No matter what our hypothesis may be, we can see viruses stand at the very threshold of life.

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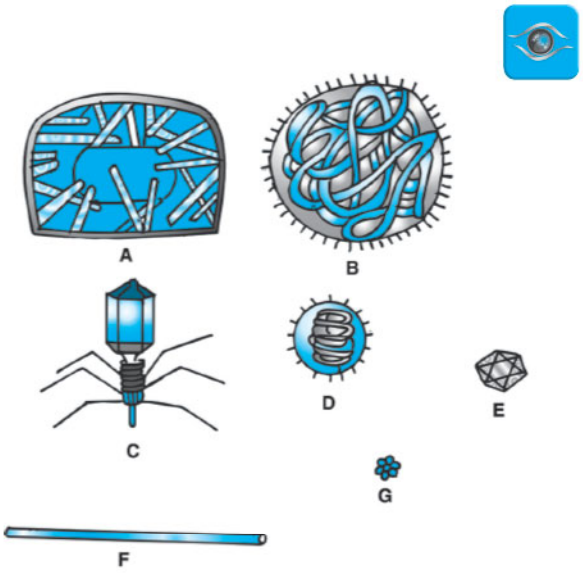

Fig. 32. Relative sizes and shapes of some viruses and bacteriophage. **A.** Vaccinia virus; **B.** Mumps virus; **C.** T_2 Bacteriophage; **D.** Influenza virus; **E.** Adenovirus; **F.** Tobacco mosaic virus; **G.** Polio virus.

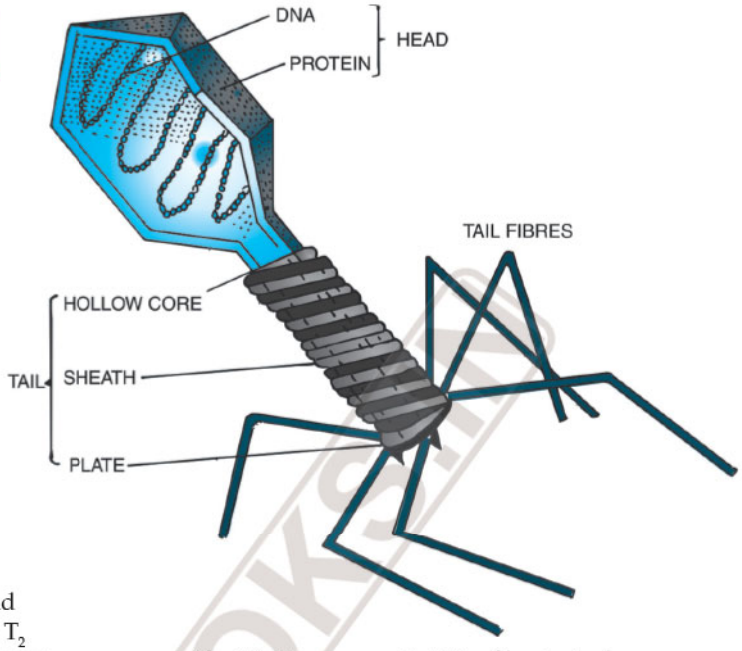

Fig. 33. Diagrammatic L.S. of bacteriophage.

PRACTICE PROBLEMS – KINGDOM SYSTEMS

1. Name the criteria used by R.H. Whittaker for five-kingdoms of life.
2. Write about the contributions of John Ray, J.D. Hooker and J.K. Maheshwari.
3. Name the books written by Carl P. Linnaeus.
4. Write one example each of five kingdoms proposed by R.H. Whittaker.
5. Write the basis of modern classification.
6. What type of organisms does kingdom Monera include?
7. What kind of organisms does kingdom Protista include?
8. Name some viral diseases.
9. Name some symptoms of viral diseases.

ANSWERS TO PRACTICE PROBLEMS

1. **(a)** Complexity of cell structure. **(b)** Complexity of body structure.
   (c) Mode of nutrition. **(d)** Ecological role.
2. **John Ray** introduced the term species. He wrote the book Historia Generalis Plantarum.
   J.D. Hooker wrote 'Flora of British India'.
   J.K. Maheshwari described the plants of India in 'Flora of Delhi'.
3. 'Systema Naturae' 'Genera Plantarum' Species Plantarum and 'Philosophia Botanica'.
4. **(a) Kingdom Monera.** (Bacteria and Cyanobacteria)
   (b) Kingdom Protista. (*Euglena*, *Amoeba*)
   (c) Kingdom Fungi. (*Penicillium*, *Rhizopus*, Mushroom)
   (d) Kingdom Plantae. (*Spirogyra*, *Marchantia*, *Pinus*, Mustard)
   (e) Kingdom Animalia. (Animal)
5. Modern Taxonomy is now based on :
   (i) evolutionary relationship,
   (ii) the similarities in the genetic codes of species,
   (iii) ecological character.
   The structural similarities are still valid.
6. Monera includes all prokaryotic organism like bacteria.
7. The kingdom Protista includes diverse kinds of unicellular and primarily aquatic, eukaryotic organisms.
8. Mumps, small pox, herpes, influenza and AIDS in humans.
9. Mosaic formation, leaf rolling and curling, yellowing and vein clearing, dwarfing and stunted growth.

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STRUCTURE OF SOME IMPORTANT VIRUSES

TOBACCO MOSAIC VIRUS (TMV)

The scientific name of this virus is *Proto-virus tabacci.* It was first discovered by **Iwanowski** in 1892, but isolated in crystallized form by **Stanley** in 1935. The virus particle is a long, cylindrical, rod shaped, helical ribovirus. It is having a length of 300 nm (3000Å) and 17.5 nm (175 Å) diameter. It has a molecular weight of 40 millions approx. (Fig. 34).

Chemical, X-ray crystallographic and electron microscopic investigations (Bernal *et.al.* Watson, Franklin *et. al.* and Casper) show that these particles consist of two parts, the protein coat and the nucleic acid. The nucleic acid **(nucleoid)** is a single stranded RNA, helically coiled forming a central core of 8 nm diameter. It consists of about 6300 nucleotides and a molecular weight of about 2.2 million. It constitutes 5.6% of the total virus composition.

The protein coat **(capsid)** consists of helically arranged subunits **(capsomeres)** around the nucleic acid core enclosing a central lumen of 4 nm diameter. It has been suggested that there are 49 subunits per three turns of the helix (approx 16.5 per turn) having a total of 2130 protein subunits in a complete particle. It means there are about 129 helical turns per particle rod. Each subunit has a molecular weight of 17500 and consists of a single polypeptide chain of 158 amino acids.

Elementary composition of the particles is, **carbon** 50%, **hydrogen** 7%, **nitrogen** 16.7%, **sulphur** 0.2% and **phosphorus** 0.54%. The protein coat can be separated from RNA. The naked RNA is still capable of infection and produce protein for its capsomeres. This shows that genetic information for complete virus particle is stored in its RNA.

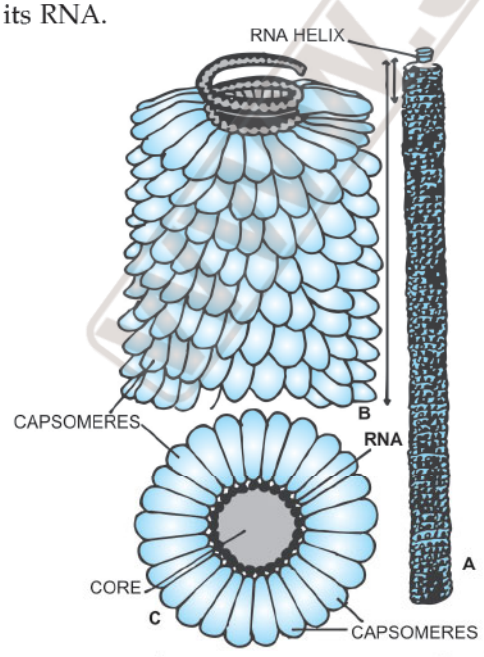

Fig. 34. TMV. A. Surface view; **B.** Structure in detail; **C.** Cross section.

BACTERIOPHAGE T_2

Its scientific name is *Phago virus secundus.* It is a coliphage as it infects colon bacillus bacterium *E.coli.* It has a bianal symmetry and looks like a tadpole. It is differentiated into **head** and a **tail.** Bacteriophages were first discovered by Twort (1915) and studied by de Herelle (1917).

The length of T_2 virus particle (Fig. 35) is about 210 nm. The head is hexagonal in outline having icosahedral pyramidal ends. It is 95 nm in length and 65 nm is diameter. The head consists of an outer protein coat (capsid) composed of about 2000 subunits of proteins (capsomeres). The protein coat surrounds a compact core of **nucleoid.** The nucleoid consists of a single, 50,000 nm long, double stranded DNA molecule. It has a molecular weight of about 2.5 million and is packed tightly in the head. The cytosine in phage DNA is hydroxymethylated.

The tail is cylindrical having a length of 115 nm, but is much narrower as compared to head. It has a diameter of 17 nm. The tail consists of an outer protein sheath of about 200 subunit enclosing a hollow core (tube) of 10 nm diameter. The tail sheath has the capacity to contract longitudinally. The lower end of the tail consists of a hexagonal tail plate (basal plate or end plate) approx. 20 nm in thickness. It has six tail pins at each corner to which are attached six, 150 nm long protein fibres known as **tail fibres.** The tail fibres normally remain folded inside the tail core. When extended they help in the attachment of the virus to the bacterium. Tip of the tail also bears some molecules of hydrolyzing enzyme—**lysozyme.**

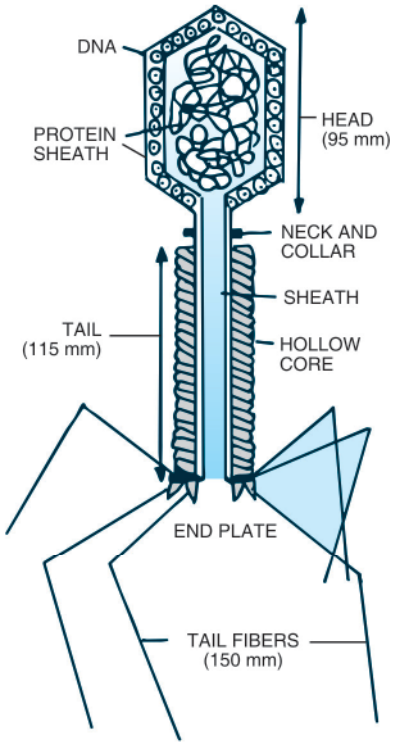

Fig. 35. L.S. through a bacteriophage (Diagrammatic).

The head and the tail are joined to each other through a short neck bearing a circular proteinaceous, their disc known as **collor.** In general, the phase particles are made up of 50% protein and 50% nucleic acid (DNA). The nucleic acid may have upto 2,00,000 nucleotides consisting roughly 600 genes.

AIDS VIRUS

It is a type of retroviruses linked with **acquired immune deficiency syndrome** or AIDS. The virus responsible for the disease in human beings is known as **human immunodeficiency virus** or HIV.

The virus particle (Fig. 36) is covered over by two **lipid** layers which are derived from the host cell. Two **glycoproteins** (proteins associated with sugars) are also associated with these lipid layers. One type of glycoprotein known as gp 41 lie within the lipid membrane and the other called gp 120 extends beyond the lipid layers and thus forms the second layer. This double layer envelope covers a double layered protein core which is made up of two types of proteins. Outer layer of this protein core is of p 18 and the inner layer is of p 24 proteins.

The protein core encloses a central core of viral **RNA.** There are two molecules of RNA associated with the molecules of enzyme **reverse transcriptase.**

AIDS were first reported in 1981. That it is caused by HIV was shown three years later. The virus attacks T_4 cells of the host. T_4 cells have their central role in regulating many processes of immune system. The virus, in addition, also affects brain and spinal chord. HIV can also cause three types of cancers in infected persons :

(i) Kaposi's sarcoma–skin tumors that spread to internal organs and cause internal bleeding and death;

(ii) Cancerous growth of skin and mucous membranes, and

(iii) Tumors in B-lymphocytes.

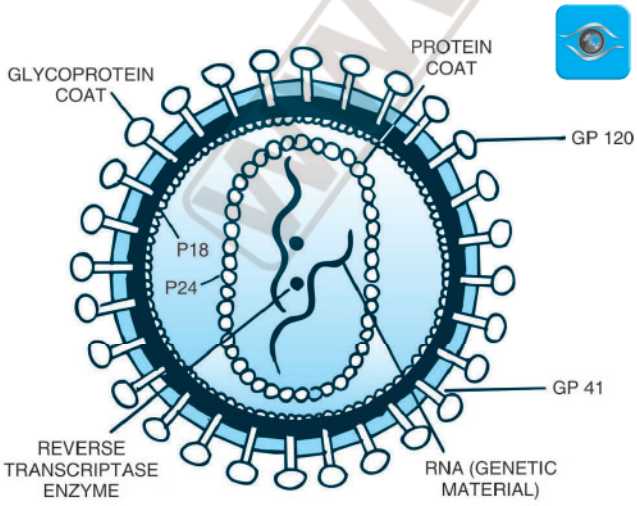

Fig. 36. AIDS virus.

It takes three to ten years of incubation during which no symptoms of AIDS are produced. At the end of incubation period, the infected people develop AIDS-related complex (ARC). It causes the depletion of T-helper cells and continuously swollen lymph glands. ARC is then followed by the appearance of the disease AIDS.

The AIDS virus could be transmitted by sexual contact, contaminated blood or blood products, sharing of drug needles contaminated with the virus and by an infected mother to her child before, during or shortly after birth. It cannot be transmitted by casual contract like shaking hands, hugging, or through food or water. The virus is easily killed by common disinfectants including household bleach. Antiviral vaccines and drugs are being developed but have not been tested yet.

MULTIPLICATION (REPLICATION) OF BACTERIOPHAGES

Multiplication of bacteriophages has been studied in T-even phages of *E.coli* by prominent workers like Delbruck, Luria and Lwoff. Lwoff suggested three stages of bacteriophages-*Extracellular Virion*, *Vegetative Phage* and *Prophage.* The complete virus particles prior of infection are **extracellular virions.** The other two stages are intracellular and are only in the form of nucleic acids. If it is free having autonomous replication, it is **vegetative phage.** It may become inserted with the bacterial DNA and is replicated alongwith it, then it is a **prophage.**

Those phages having the capacity to become prophages are called "**Temperate phages**" and those which lack this property are called "**Virulent phages**". The multiplication in both of these types can be studied separately in **lytic cycle** (for virulent phages) and **lysogenic cycle** (for temperate phages).

Lytic cycle

The multiplication process of a virulent phage is called lytic cycle because the host bacterial cell is lysed at the end. This process is divided into following stages :

1. Adsorption (Fig. 37). It is the attachment of virus particle to the specific host bacterial cell. The attachment is at the specific **receptor sites** present on the wall of host cell. T-even phages (T_2, T_4 etc.) attach with the help of their tail fibres at the host receptor sites.

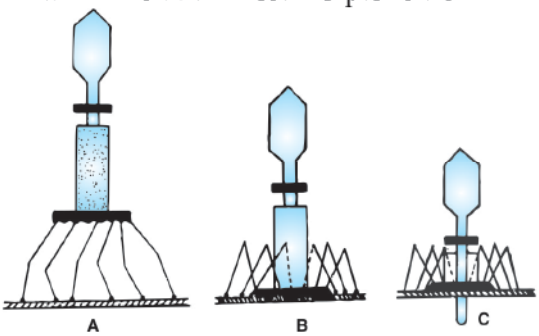

Fig. 37. Mechanism of attachment and penetration of bacteriophage.

2. Penetration (Fig. 37). The next phase is the injection of nucleic acid of the virion into the host cell. The nucleopeptidal host cell wall is hydrolyzed by **lysozyme** present at the tip of the tail making a **hole,** through which the viral nucleic acid is injected into the host cell via tail tube. This happens when tail fibres, after attachment, bent, bringing the base plate in contact with the bacterial cell wall. The tail sheath contracts and the central tube (needle) is pushed through the hole in the wall. All this process is an active process and takes place on the expense of ATP. The protein coats remaining outside, attached to the host cell wall, are called "**Ghosts**".

3. The eclipse stage. This stage shows the following viral DNA activity inside the host cell. **(i)** immunity against further infection by phages of the same type by the production of specific enzyme called "**repressors**" **(ii)** suppression of all cellular activity of the host **(iii)** synthesis of new enzymes by phage DNA utilizing amino acid pool of the host cell. These are called *Early Proteins* **(iv)** These enzymes are utilized to seal the hole in the cell wall, to destruct the DNA of the host **(v)** the fresh DNA molecules then synthesize a new type of proteins called *Late Proteins* identified as viral coat proteins and viral lysozymes. The coat proteins form monomers which are then assembled into capsomeres and other viral components.

4. Maturation. It is the assembly of various components into mature or complete virions. Head and tails are first assembled separately and then the two are attached to form hundreds of new phage particles. The time period between the injection of viral nucleic acid and the first appearance of new phage progeny is the **eclipse period,** which is about 12 minutes in T_2 phages. The total time taken from the introduction of nucleic acid to the rupture of host cell wall is called **Latent period.** It is about 18 minutes for T_2 phages.

5. Lysis and release of new virions—The cell wall bursts at the end of latent period and the virions are liberated. This phenomenon is called **lysis.** The number of virions produced per host cell is specific and is termed as the **burst size.** Generally is it 200 – 300. The main stages of lytic cycle have been shown in Fig. 38.

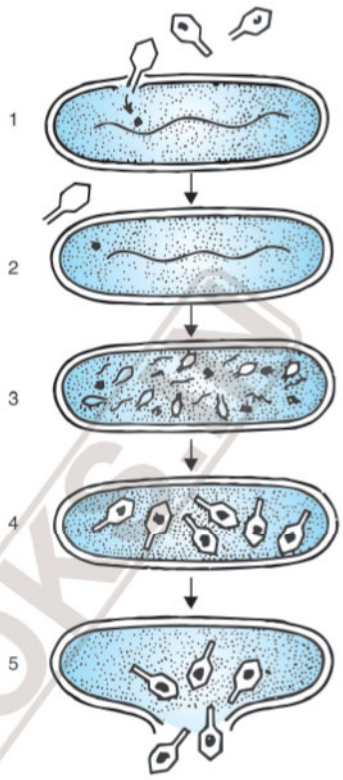

Fig. 38. The stages of lytic cycle of bacteriophages.

Lysogenic cycle

It is associated with the replication of **temperate** phages **(Prophages).** Sometimes, a virus may cause the immediate lysis of the host cell but become associated with the host genome. This phenomenon is known as **Lysogeny.** The phages are temperate in prophage states. The cycle of temperate phage is called **lysogenic cycle** and the bacterium which harbours the phage is called **lysogenic bacterium.** The lysogenic cycle of λ bacteriophage is shown in Fig. 39.

In prophage condition, the phage DNA is replicated alongwith bacterial genome. UV irradiation and presence of hydrogen peroxide may cause excision of the prophage from the bacterial genome to convert it into virulent state. Then, it goes vegetative lytic cycle as described earlier. This conversion of prophage into virulent state is called "**induction**".

Table 10. Differences between Lytic and Lysogenic phases of viruses.

Characters	Lytic phase	Lysogenic phase
1. **Integration of DNA**	Viral genome does not integrate with host DNA	Viral genome gets integrated with host DNA to form **prophage** or **provirus.**
2. **Hydrolysis of host DNA**	Occurs	Does not occur.
3. **Replication**	Prophage replicates once along with replication of host genome to transfer a single particle to daughter cell.	Viral genome replicates many times to form many copies in same host cell.

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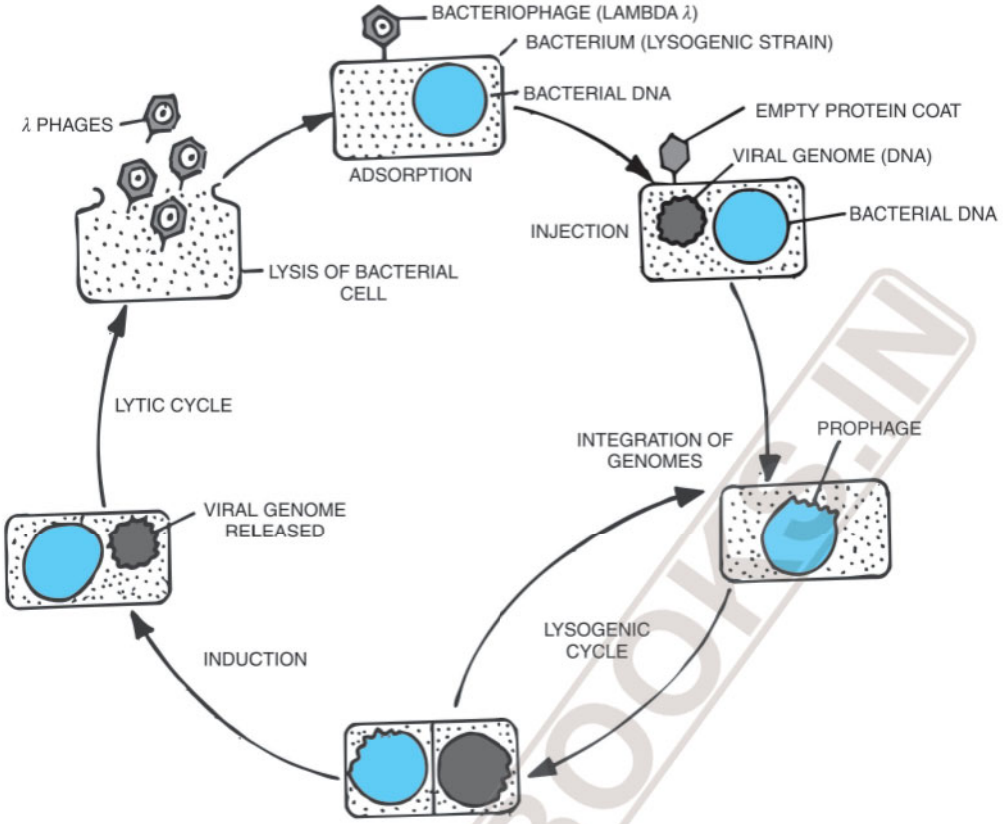

Fig. 39. Lysogenic cycle of λ bacteriophage.

MYCOPLASMA

Mycoplasma i.e. PPLO (Pleuropneumonia like organism) is the causative agent of pleuroneumonia, a contagious disease of cattle. **Louis Pasteur** observed this organism with the smallest cell is not a bacterium and can be observed only under electron microscope. PPLO also called as MLO (Mycoplasma like organism).

It shows the following characteristics :

1. Being smallest organism (0-1 micron in diameter) can pass through fine pored filter.

2. Can be seen only under electron microscope.

3. It is able to grow on non-living medium.

4. Internal organisation mostly resembles typical bacterium.

5. It bears plasma membrane, ribosomes with complete protein synthetic machinery.

6. Nucleus is not well developed and shows the absence of nuclear envelope.

7. As many as 40 enzymes have been reported from cell of *Mycoplasma.*

8. It is non-motile, gram negative and contains DNA and RNA.

Diseases caused by *Mycoplasma*

1. Little leaf of brinjal
2. Sandal spike
3. Citrus greening
4. Grassy shoot of sugarcane
5. Rice yellow dwarf
6. Cotton stenosis

SHAPE

Mycoplasma varies in shape. Spherical forms has the size of 80–150 mμ.

Pleomorphic forms measure about 210–245 mμ. In this type, filamentous and branched forms have also been reported. *Mycoplasma* occurs in soil, sewage, human and plants.

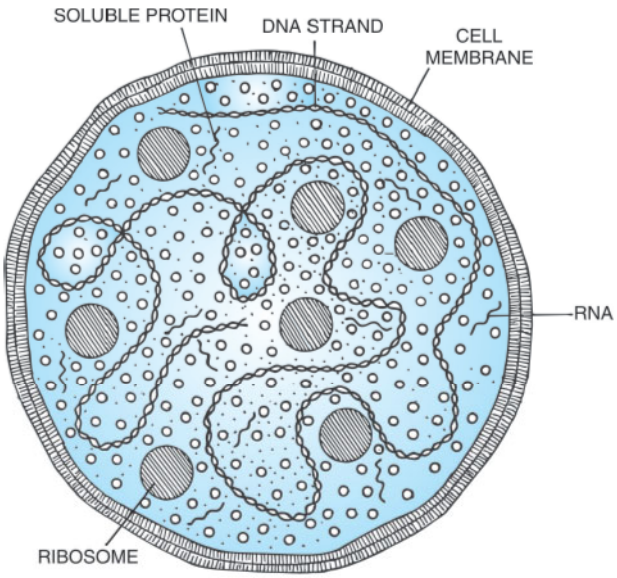

Fig. 40. *Mycoplasma.* Electron micrograph of *Mycoplasma* cell.

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LICHENS

Morphology

1. Lichens are formed due to intimate combination of an alga and fungus and provide classic example of symbiosis.

2. The fungal component is called mycobiont and the algal component is known as phycobiont. According to their growth forms, lichens may be divided into three principle types :

A. Crustose Lichen (Fig. 41)

1. Crustose lichens show crust like growth.

2. Thallus is very small in size, flat irregularly lobed and inconspicuous in growth.

3. It appears as if the thallus is embedded in the substratum.

4. Small fruiting bodies may be visible, which may be of apothecial type.

5. The apothecia contain asci and ascospores.

B. Foliose Lichen (Fig. 41)

1. The thallus is like a dry forked leaf.

2. Foliose lichen is flat, irregularly lobed with a distinct upper and lower side.

3. The thallus is attached with substratum by means of rhizines.

4. Rhizines are developed on the lower surface of thallus.

5. The upper side shows the presence of number of fruiting bodies.

6. The reproductive bodies are quite prominent and cup like i.e. apothecial in nature.

7. The apothecia bear asci and ascospores and are dark coloured.

8. Foliose lichens are usually terricolous (found growing on trees) in the hilly regions.

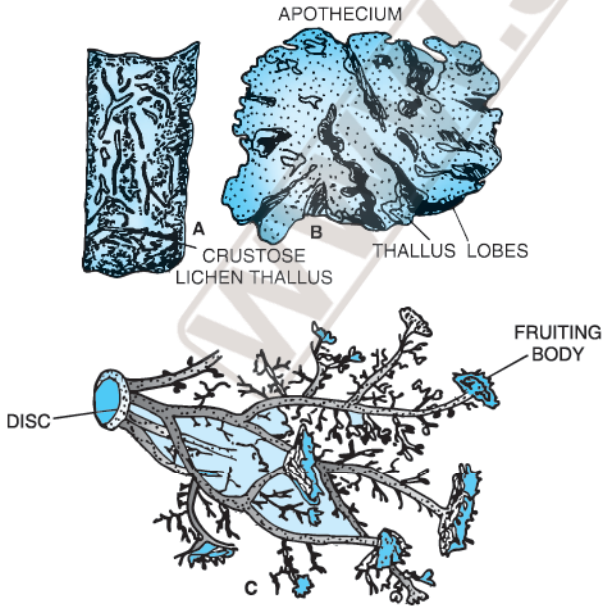

Fig. 41. Forms of lichens, **A.** Crustose (*Graphis* sp.); **B.** Foliose (*Parmelia*); **C.** Fruiticose (*Usnea*).

C. Fruiticose Lichen (Fig. 41)

1. Fruiticose lichen is cylindrical, well branched and pendent with hair like outgrowths.

2. Thallus is usually found attached with tree trunks (terricolous).

3. At the tip of branch, large apothecial type of fruiting bodies are present.

4. Thallus looks like a mini shurblet.

5. Conspicuous hairy growth is present at the periphery of apothecia.

MYCORRHIZA

Mycorrhiza is the root fungus association. The mycorrhizal roots are usually covered with fungal woolly outgrowth. The association may be of two types :

(a) Ectotrophic (ectomycorrhizae) : When the hyphae do not penetrate deep into root and remain superficial.

(b) Endotrophic (endomycorrhizae) : When hyphae grow within root surface.

In *Pinus* mycorrhizal roots are found in the upper zone of soil. They are irregular and swoller structures. Root cap is absent. Even root hairs are absent on such roots. These roots help in absorption of organic substance from soil. The fungal partners are usually those which are capable of breaking down the plant cell in a limited way. However, these hyphae survive well on sugars supplied by plant. Fungus growth does not cause any harm to the plant. Fungi are confined to fixed area in plant. Along with water, phosphorus, nitrogen are absorbed. Fungi also provide growth promoting and antimicrobial substances. In *Pinus* (Fig. 42) mycorrhizae are of three types *i.e.* **coralloid, tuberous** and **nodulated.** The dichotomously divided roots are called coralloid. Tuberous and nodulated mycorrhizal roots remain stumpy. Orchids which are found as epiphytes often bear mycorrhizal roots. Mycorrhizal roots are said to be essential for the survival of certain orchids.

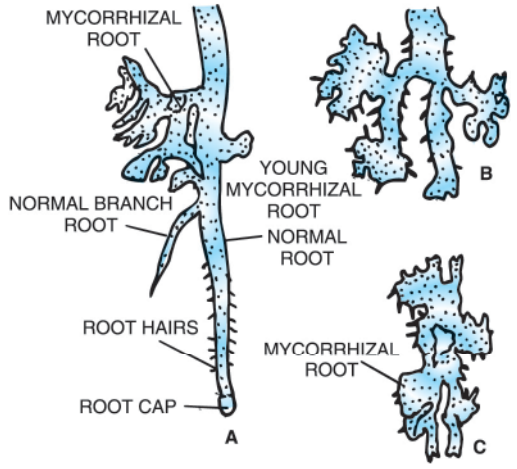

Fig. 42. *Pinus* **A.** Young normal root bearing mycorrhizae; **B.** Coralloid type of mycorrhizal root; **C.** Part of normal root bearing tuberous mycorrhizae.

ADDITIONAL USEFUL INFORMATIONS ABOUT KINGDOM SYSTEMS FOR COMPETITIVE EXAMINATIONS

- *According to **Binomial nomenclature**, every organism must have a scientific name in latin or latinised.*
- *In case of two or more names are given, the oldest i.e. the name given first is recognised as valid name and all other names are called synonyms.*
- *Linnaeus thought species to be static, constant, fixed and immutable. But Lamarck and Darwin rejected the static concept and gave the view that species is dynamic.*
- *Higher the category, higher the number of organisms in it. Higher the category, fewer will be number of common characters.*
- *Term **antibiotic** was used by **Waksman**—the discoverer of streptomycin.*
- *Biological classification is not rigid and is subject to modification as more and more is learnt about organisms.*
- ***Phylogenetic classification** reflects the evolutionary relationships of organisms. The organisms related evolutionary are usually similar morphologically also.*
- *Euglena is considered to be connecting link between prokaryotes and eukaryotes.*
- *The terms prokaryotes and eukaryotes were coined by Fott.*
- ***S. Prusnier** was awarded nobel prize in 1997 for his contribution to infectious agents called **Priona** which are made up of proteins without any nucleic acids.*
- *Numerical taxonomy is same as **phenetic taxonomy.** A family tree based on numerical of phenetic taxonomy is called **dendrogram.***
- ***Phylogeny** was introduced by **Homock** but concept was established by **Haeckel.***

ANGIOSPERMS AND CLASSIFICATION UPTO CLASS :

They are flowering plants. They dominate vegetation of earth because of the following characters.

(a) Seeds are always enclosed inside the fruit.

(b) Very well developed vascular tissue is present where xylem vessels and phloem with companion cells are present.

(c) Flowers are the organs of sexual reproduction. These flowers show essential and non-essential parts. Calyx and corolla are non-essential whorls whereas androecium and gynoecium are essential whorls.

(d) Androecium is made up of stamens. Anthers of stamens produce pollen grains (microspores) which further develop into male gametophyte and male gametes.

(e) Gynoecium is made up of carpels. Inside the ovary female gametophyte- 7 celled, 8 nucleated structure- embryo sac develops. Here egg apparatus is present which contains female gamete i.e. egg. Archegonia are absent.

(f) Pollination occurs by wind, water, insects or animals.

(g) Male gametes are nonmotile in angiosperms and they are carried to the egg female gamete - by pollen tube.

(h) Double fertilization is the characteristic feature of angiosperms. In this process, both the male gametes take part in fertilization. One male gamete fuses with egg to form zygote. The other fuses with secondary nucleus forming primary endosperm nucleus. This primary endosperm nucleus further divides and redivides to form **triploid endosperm**. Thus endosperm formation is post fertilization event. This endosperm nourishes the developing embryo.

(i) After fertilization, ovary changes into fruit and ovules change into seeds. Zygote develops into an embryo. The embryo gets nourishments either from endosperm or from cotyledons.

CLASSIFICATION OF ANGIOSPERMS

Angiosperms are further divided into two classes :

(i) Dicotyledonae **(ii)** Monocotyledonae

(i) Dicotyledons : (Dicots) are characterized by

(a) Presence of 2 cotyledons in embryo.

(b) Tap root system

(c) Branched stem with vascular bundles arranged in a ring.

(d) Leaves with reticulate venation.

(e) Flowers show tetra or pentamerous symmetry e.g. Sunflower, Hibiscus, Cotton, Carrot etc.

(ii) Monocotyledons : It is characterized by presence of

(a) Single cotyledon in an embryo.

(b) Adventitious or fibrous root system.

(c) Unbranched stem with scattered vascular bundles.

(d) Leaves with parallel venation

(e) Flowers show trimerous symmetry. e.g. Maize, Jowar, Onion, Garlic, Sugarcane etc.

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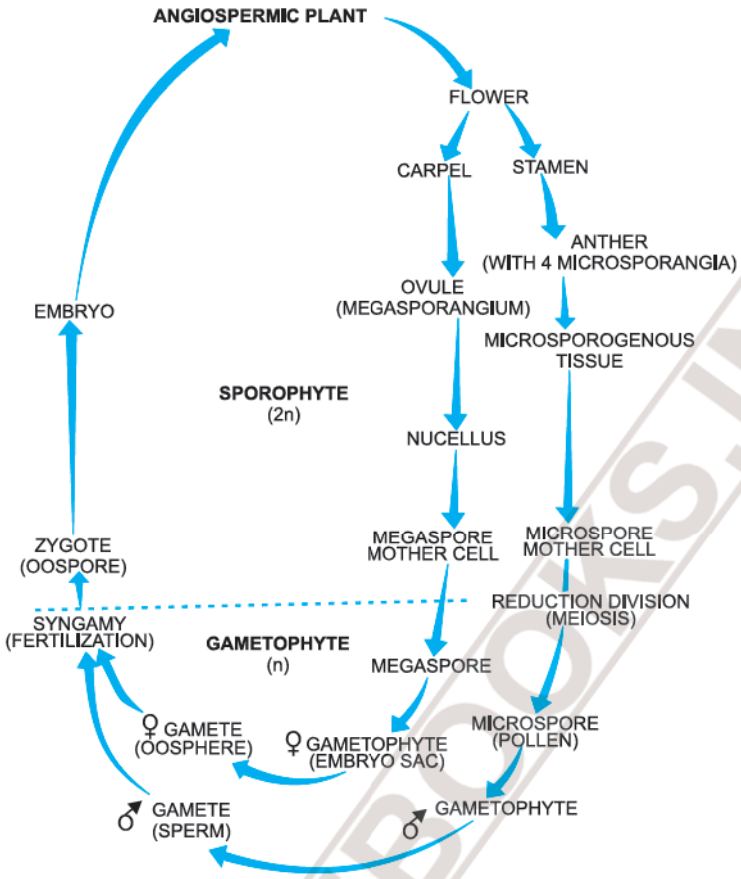

Fig. 43. Graphical life cycle of an angiospermic plant.

Table 11. Some distinguishing characters of Dicots and Monocots.

Plant organ	Dicots	Monocots
Root	Tap, Adventitious or both	Only adventitious
Stem	Vascular bundles arranged in ring with central pith (dictyostele)	Vascular bundles scattered (atactostele)
Leaves	Mostly with reticulum (network)	Usually parallel veined
Cotyledons	Two	One
Floral parts	Five or multiple of 5, rarely 4	Three or multiple of 3, rarely 4, never 5

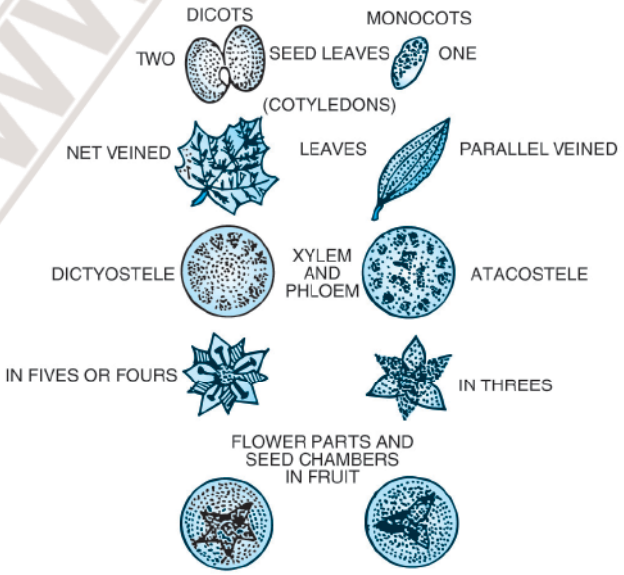

Fig. 44. Some of the differences between dicots and monocots.

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PRACTICE PROBLEMS

1. Write any three drawbacks of kingdom protista.
2. How lytic cycle deffers from lysogenic cycle ?
3. What are viroids ?
4. Name the kingdom of multicellular consumers.
5. Name the kingdom of prokaryotes.
6. Name the (i) Smallest animal virus; (ii) Largest animal virus; (iii) Smallest plant virus; (iv) Largest plant virus.

ANSWERS TO PRACTICE PROBLEMS

1. (i) Dinoflagellates bear a different type of nuclear matter which lacks histone. In this case, spindle apparatus is not formed during cell division.
   (ii) It is difficult to find differences between protistan algae and algae of kingdom plantae.
   (iii) Protistans appear to be polyphyletic.
2. Lytic cycle is virulent form of life cycle. Lysogenic cycle is non–virulent or temperate form of life cycle. In lytic cycle, viral genome does not produce a repressor. A repressor is formed to check the destruction of host DNA in lysogenic cycle. DNA of host cell is hydrolysed in lytic cycle. DNA of host cell is not harmed in lysogenic cycle.
3. Viroids are smaller than viruses. They lack protein coat. They are RNA particles with low molecular weight and parasitize only plants.
4. Animalia.
5. Monera
6. (i) Smallest animal virus : Foot and mouth virus ;
   (ii) Largest animal virus : Pox virus;
   (iii) Smallest plant virus : Tobacco mosaic satellite virus, Alfalfa mosaic virus
   (iv) Largest plant virus : Citrus tristeza virus .

CHAPTER SUMMARY

- **R.H. Whittaker** (1969) proposed **five kingdom classification.**
- Bacteria are sole members of **Kingdom Monera.**
- **Archaebacteria** are found in most harsh habitats.
- **Cyanobacteria** (blue green algae) are photosynthetic autotrophs. Some of these can fix atmospheric nitrogen in **heterocysts**.
- **Mycoplasma** completely lack cell wall and can survive without oxygen.
- All single celled eukaryotes are placed in **Kingdom Protista**.
- **Chrysophytes** include diatoms and golden algae (desmids).
- **Dinoflagellates** are mostly marine and photosynthetic.
- Majority of **Euglenoids** are fresh water organisms found in stagnant water.
- **Slime moulds** are saprophytic protists.
- All **Protozoans** are heterotrophs and live as predators or parasites.
- With the exception of yeast which are unicellular, fungi are filamentous.
- Mycelium is aseptate and coenocytic in members of **phycomycetes.**
- Members of **ascomycetes** are saprophytic, decomposers, parasitic or coprophilous.
- Common forms of basidiomycetes are **mushrooms**, bracket fungi or puffballs.
- **Deuteromycetes** are also known as imperfect fungi because only vegetative or asexual phase occur in them.
- **Kingdom plantae** has two distinct phases—The diploid saprophytic and haploid gametophyte.
- **Kingdom animalia** is characterized by heterotrophic eukaryotic organisms that are multicellular and their cells lack cell walls.
- **Viroids** were discovered by Diener (1971) which are smaller than viruses.
- **Lichens** show symbiotic association.

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KEY TERMS

Adaptive radiation	:	The process of evolution from a single ancestral species of a variety of forms which occupy somewhat different habitats.
Ancestor	:	One from which an organism has descended.
Bacteriophage	:	Viruses which parasitize bacteria.
Decomposer	:	An organism that feeds upon dead organisms breaking them down into simpler substances.
Eukaryote	:	An organism whose genetic material (DNA) is enclosed by membranes (the nuclear membrane) to form a nucleus.
Fermentation	:	It is a form of anaerobic respiration and is seen in certain bacteria and in yeasts. The incompletely oxidized products of alcoholic fermentation—ethanol and carbon dioxide are important in brewing and baking industry.
Fungi	:	A diverse group of mainly terrestrial organisms separated from other plants by their lack of chlorophyll. They are generally saprophytic or parasites.
Lichens	:	A group of composite plants and lichens which are symbiotic associations between a green or blue-green alga and a fungus.
Metazoa	:	A kingdom of multicellular animals whose bodies are composed of specialised cells grouped together to form tissues and that possess a coordinating nervous system.
Micrometer	:	Symbol µm, a unit of length equal to 10^{-6} metre (one millionth of a metre).
Nucleoid	:	The region of a bacterium or blue-green alga containing DNA and not enclosed by membranes.
Palaeontology	:	It deals with the finding, cataloguing and interpreting the abundant and direct evidence of life in ancient times.
Phylogeny	:	The evolutionary history of any group of organisms is termed its phylogeny.
Producers	:	The first trophic level in a food chain. Producers are those organisms that can build up foods from inorganic materials *i.e.* green plants.
Protista	:	A kingdom of unicellular eukaryotes.
Species	:	One population of organisms, all the members of which are able to breed amongst themselves.
Taxonomy	:	It deals with identification, nomenclature and classification of different types of organisms.

NCERT FILE Solved

NCERT Exercise Questions

1. Discuss how classification systems have undergone several changes over a period of time?

Ans. Since dawn of civilisation, there have been many attempts to classify the living organisms.

(i) Aristotle was the earliest to attempt to give a classification with scientific basis.

(ii) Linnaeus classified all living organisms into two large kingdoms : **(a) Kingdom Plantae; (b) Kingdom Animalia.** This system did not distinguish between the eukaryotes and prokaryotes, unicellular and multicellular organisms and photosynthetic (green algae) and non-photosynthetic (fungi) organisms.

(iii) Haeckel (1866) identified a **Kingdom Protista.**

(iv) Copeland gave **Four Kingdom System** of classification called **Monera, Protista, Metaphyta** and **Metazoa.**

(v) Five Kingdom System of classification was given by **K. H. Whittaker** (1969). The five kingdoms are: **Monera, Protista, Fungi, Plantae** and **Animalia** (For details consult chapter–2).

Whittaker has not described viruses and lichens. Stanley discussed virus, viroids etc.

2. State two economically important uses of :

(a) Heterotrophic bacteria

(b) Archaebacteria

Ans. (a) Heterotrophic bacteria : (i) They are helpful in making curd from milk; **(ii)** They are also useful

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in production of antibiotics, fixing nitrogen in legume roots.

(b) **Archaebacteria : (i)** Methanogens are present in the guts of several ruminant animals like cows and buffaloes and they are responsible for the production of methane (biogas) from dung of such animals; **(ii)** Due to different cell wall structure than bacteria, they are able to tolerate extreme conditions.

3. What is the nature of cell walls in diatoms?

Ans. The walls are embedded with silica and are indestructible. Diatoms have left behind large amount of cell wall deposits in their habitat and this accumulation over billions of years is called **diatomaceous earth.**

4. Find out what do the terms algal bloom and red tide signify?

Ans. **Algal bloom.** High quantity of nitrates and phosphates in water bodies due to surface run off leads to blooming of agae.

Red tide. Some dinoflagellates like *Gonyaulax* when present in high quantity in sea imparts red colour to water and are called **red tide.** However due to algal blooms and red tide animal life declines due to toxins and deficiency of oxygen inside water.

5. How are viroids different from viruses?

Ans.

Viroids	Viruses
Viroids are smallest (smaller than viruses) self replicating RNA particles and do not bear protein coat.	Viruses are smaller, host specific particles made up of nucleoid (RNA of DNA) and capsid (protein coat).

6. Describe briefly four major groups of Protozoa.

Ans. Refer table 4 of Chapter-2.

7. Plants are autotrophic. Can you think of some plants that are partially heterotrophic?

Ans. Plants include chlorophyll containing autotrophic organisms. Some insectivorous and parasitic plants are partially heterotrophic.

Partially heterotrophic insectivorous plants : Bladderwort and Venus Fly Trap.

Parasitic heterotrophic plant : *Cuscuta.*

8. What do the terms phycobiont and mycobiont signify?

Ans. **Phycobiont.** The algal component of a lichen is called phycobiont.

Mycobiont. The fungal component of a lichen is called mycobiont.

Algae and fungi live in association with one another and show **symbiosis.**

9. Give a comparative account of classes of kingdom fungi under the following :

(i) Mode of nutrition (ii) Mode of reproduction

Ans. **(i) Mode of nutrition.** Fungi lack chlorophyll and thus do not show the process of photosynthesis. They exhibit **heterotrophic** mode of nutrition. They obtain their nutrition from external source by process of extracellular digestion and absorption of digested material.

According to mode of nutrition, fungi are of two types :

(a) Parasites. Such fungi are found in intimate association with another living organism from which they derive food for their survival.

(b) Saprophytes. Such fungi obtain their food from non-living decaying organic matter.

(ii) Mode of reproduction :

S.No.	Zygomycetes	Ascomycetes	Basidiomycetes
1.	Asexual reproduction by **sporangia.**	Asexual reproduction by **conidia.**	Asexual reproduction by **fragmentation.**
2.	Sexual reproduction by **zygospores.**	Sexual reproduction by **asci.**	Sexual reproduction by **basidia.**

10. What are the characteristic features of Euglenoids?

Ans. Refer chapter-2.

11. Give a brief account of viruses with respect to their structure and nature of genetic material. Also name four common viral diseases.

Ans. For account of viruses, refer chapter-2.

Common viral diseases. (i) Influenza; **(ii)** Chicken pox; **(iii)** Rabies; **(iv)** AIDS.

12. Organise a discussion in your class on the topic "Are viruses living or non-living?"

Ans. Arrange the discussion with the help of your teacher and keep in mind following characters :

Viruses are enigmatic biological entities. They possess characters of non-living but show some properties of living.

Inanimate (non-living) characters

1. Viruses show property of crystallization. TMV and many other plant, animal and bacterial viruses have been crystallized.
2. Viruses show sedimentation properties.
3. They can be separated into their components by treating with detergents.
4. They do not show their own activity but are dependent upon living cells for their own existence.
5. They lack energy producing enzyme systems like respiration.
6. Viruses lack cellular organization.
7. They have only one type of nucleic acid (DNA or RNA), while living organisms possess both.
8. Viruses lack growth and cell division for their multiplication.

Animate (living) properties

1. They show the capacity to multiply in number within the living cells of the organisms.
2. Viruses show host specific intracellular parasitism, the property associated with living organisms only.
3. They can undergo mutations to give rise to new variants.
4. They are infectious and can be transmitted from one host to another.

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5. They are sensitive to temperature, chemicals and radiations.
6. They possess antigenic properties.
7. Viruses have the capacity to bring about enzymatic changes *in vitro*.

So, on the basis of their inanimate characters, the viruses cannot be considered as organisms. They are **acellular** or **non-cellular**, but again it is difficult to ignore their living properties and cannot be considered as inert chemicals. For this reason, Lwoff, a French scientist, said, "A virus is a virus". It is neither an organism nor a non-living inert chemical.

NCERT Exemplar Problems

A. MULTIPLE CHOICE QUESTIONS

1. All eukaryotic unicellular organisms belong to :
   (a) Monera (b) Protista
   (c) Fungi (d) Bacteria
2. The five kingdom classification was proposed by :
   (a) R.H. Whittaker (b) C. Linnaeus
   (c) A. Roxberg (d) Virchow
3. Organisms living in salty areas are called as :
   (a) Methanogens (b) Halophiles
   (c) Heliophytes (d) Thermoacidophiles
4. Naked cytoplasm, multinucleated and saprophytic are the characteristics of :
   (a) Monera (b) Protista
   (c) Fungi (d) Slime molds
5. An association between roots of higher plants and fungi is called :
   (a) Lichen (b) Fern
   (c) Mycorrhiza (d) BGA
6. A dikaryon is formed when :
   (a) Meiosis is arrested
   (b) The two haploid cells do not fuse immediately
   (c) Cytoplasm does not fuse
   (d) None of the above
7. *Contagium vivum fluidum* was proposed by :
   (a) D.J. Ivanowsky
   (b) M.W. Beijerinek
   (c) Stanley
   (d) Robert Hook
8. Mycobiont and Phycobiont are found in :
   (a) Mycorrhiza (b) Root
   (c) Lichens (d) BGA
9. Difference between Virus and Viroid is :
   (a) Absence of protein coat in viroid but present in virus
   (b) Presence of low molecular weight RNA in virus but absent in viroid
   (c) Both a and b
   (d) None of the above
10. With respect to fungal sexual cycle, choose the correct sequence of events :
    (a) Karyogamy, Plasmogamy and Meiosis
    (b) Meiosis, Plasmogamy and Karyogamy
    (c) Plasmogamy, Karyogamy and Meiosis
    (d) Meiosis, Karyogamy and Plasmogamy
11. Viruses are non-cellular organisms but replicate themselves once they infect the host cell. To which of the following kingdom do viruses belong to?
    (A) Monera
    (b) Protista
    (c) Fungi
    (d) None of the above
12. Members of phycomycetes are found in :
    (i) Aquatic habitats
    (ii) On decaying wood
    (iii) Moist and damp places
    (iv) As obligate parasites on plants
    Choose from the following options
    (a) None of the above (b) (i) and (iv)
    (c) (ii) and (iii) (d) All of the above

ANSWERS

1. (b); **2.** (a); **3.** (b); **4.** (d); **5.** (c); **6.** (b); **7.** (b); **8.** (c); **9.** (a); **10.** (c); **11.** (d); **12.** (d)

B. VERY SHORT ANSWER TYPE QUESTIONS

1. What is the principal underlying the use of Cyanobacteria in agricultural fields for crop improvement?

Ans. Some cyanobacteria like *Nostoc*, *Anabaena* can fix the nitrogen due to presence of heterocysts.

2. Suppose you accidentally find an old preserved permanent slide without a label. In your effort to identify it, you place the slide microscope and observe the following features:

(a) Unicellular

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(b) **Well defined nucleus**

(c) **Biflagellate–one flagellum lying longitudinally and other transversely**

What would you identify it as? Can you name the kingdom it belongs to?

Ans. (i) Dinoflagellate (ii) Kingdom Protista.

3. **How is five-kingdom classification advantageous over the two kingdom classification?**

Ans. Five kingdom system is more advantageous due to following reasons:

(i) Based on complexity of cell structure (prokaryote or eukaryote)

(ii) Body structure (unicellular or multicellular)

(iii) Life style

4. **Polluted water bodies have usually very high abundance of plants like *Nostoc* and *Oscillatoria*. Give reasons.**

Ans. It is to due to nutrient enrichment in polluted water bodies (deposition of phosphate containing detergents). It increases the growth of some algae.

5. **Are chemosynthetic bacteria autotrophic or heterotrophic?**

Ans. Chemosynthetic bacteria can oxidise inorganic substances like ammonia, nitrites and nitrates thereby able to utilise energy. Thus chemosynthetic bacteria can be called as autotrophs.

6. **The common name of pea is simpler than its botanical (scientific) name *Pisum sativum*. Why then is simple common name not used instead of the complex scientific/ botanical name in biology?**

Ans. Refer '**Disadvantages of common name (vernacular name)** from **Birnomial nomenclature** of this chapter.

7. **A viruses is considered as a living organism and an obligate parasite when inside a host cell. But virus is not classified alongwith bacteria or fungi. What are the characters of virus that are similar to non-living objects?**

Ans. Non-living characters of virus:

(i) Outside the host viruses are inert and cannot reproduce at their own.

(ii) Viruses can be crystallised, lack cellular organisation.

(iii) They are incapable of growth and division.

7. **In the five kingdom system of Whittaker, how many kingdoms are eukaryotes?**

Ans. Out of total five kingdoms, following four kingdoms are eukaryotes.

(i) Protista (ii) Fungi

(iii) Plantae and (iv) Animalia

Kingdom Monera is prokaryotic.

C. SHORT ANSWER TYPE QUESTIONS

1. **Diatoms are also called 'pearls of ocean'. Why? What is diatomaceous earth?**

Ans. Diatoms are also called **pearls of ocean** due to:

(i) They are siliceous, thus deposit silica in ocean after their death.

(ii) They are autotrophic and major producers in ocean.

(iii) Diatomaceous earth with deposits of silica is chemically inert, porous, absorbent and fireproof.

2. **There is a myth that immediately after heavy rains in forest mushrooms appear in large number and make a very large ring or circle, which may be several metres in diameter. These are called as 'fairy rings' Can you explain this myth of fairy rings in biological terms.**

Ans. Circles appear due to underground mycelium of mushroom which appear centrifugally. From this mycelium fruiting bodies (basidiocarps) appear in rings. Gradually this mycelium widens and central mycelium perishes. Due to this diameter of the ring also increases every year.

3. ***Neurospora* an ascomycetes fungus has been used as a biological tool to understand the mechanism of plant genetics much in the same way as *Drosophila* has been used to study animal genetics. What makes *Neurospora* so important as a genetic tool?**

Ans. *Neurospora* can be grown easily under laboratory conditions. Mutations can be induced easily. Ascospores formed by meiotic division can be observed and separated easily from ascus. Each ascospore can be grown further on suitable culture medium.

4. **Cyanobacteria and heterotrophic bacteria have been clubbed together in Eubacteria of kingdom Monera as per the "Five Kingdom Classification" even though the two are vastly different from each other. Is this grouping of the two types of taxa in the same kingdom justified? If so, why?**

Ans. Both have been clubbed together due to:

(i) Do not possess well defined nucleus as nucleus lacks nucleolus and nuclear membrane.

(ii) DNA lies freely in cytoplasm.

(iii) Both bear 70S type of chromosmoses.

5. **At a stage of their cycle, ascomycetes fungi produce the fruiting bodies like apothecium, perithecium or cleistothecium. How are these three types of fruiting bodies different from each other?**

Ans. Apothecium, perithecium and cleistothecium differ in shape i.e. cup shaped; flask shaped and closed. For details refer '**Fungi**' of 'Plant Kingdom' of chapter 3.

6. **What observable features in *Trypanosoma* would make you classify it under kingdom Protista?**

Ans. Unicellular and eukaryotic. It reproduces by binary fission details refer '*Zooflagellata*' of Kingdom *Protista*' Fig. 12 Chapter-2.

7. **Fungi are cosmopolitan, write the role of fungi in your daily life.**

Ans. Fungi are heterotrophic due to absence of chlorophyll. They become either parasites or saprophytes.

(i) Fungi like *Agaricus*, *Morchella* are nutritious and are used as food.

(iii) Yeasts are used for fermentation.

(iv) Fungus *Pythum* (Root rot fungus) is killed by *Trichoderma* (a soil inhabiting fungus).

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D. LONG ANSWER TYPE QUESTIONS

1. Algae are known to reproduce asexually by variety of spores under different environmental conditions. Name these spores and the conditions under which they are produced.

Ans. **(i) Zoospores.** Flagellated and produced under favourable conditions.

(ii) Aplanospores. Unicellular, non-motile and thin walled spores and produced under less unfavourable conditions.

(iii) Hypnospores. Thick walled non-motile spores and produced under high unfavourable conditions.

(iv) Akinetes. Thick walled vegetative cells produced in filaments to tolerate the unfavourable conditions. Also refer '**Algae**' of 'Plant Kingdom' tables 3,4 and 5 of Chapter 3.

2. Apart from chlorophyll, algae have several other pigments in their chloroplast. What pigments are found in blue-green, red and brown algae that are responsible for their characteristic colours?

Ans. Refer table 1 of chapter 3.

3. Make a list of algae and fungi that have commercial value as food, chemicals, medicine and fodder.

Ans. Refer Ans. 7 of short Answer Type Questions and '**Economic importance of Algae**' Chapter 3.

4. Biological classification is a dynamic and ever evolving phenomenon which keeps changing with our understanding of life forms. Justify the statement taking any two examples.

Ans. Biological classification is undergoing changes. In the beginning, only few characters were picked up arbitrarily in artificial system of classification. Gradually, more characters were used for classification. Two kingdom system of classification was revised to three kingdom system of classification. In this kingdom Protista was added. It was followed by four kingdom system by Copeland (1955). Kingdom monera was added in it. Five kingdom system of classification (Whittaker, 1963) came into force. Woese has added another kingdom called Archaea. Also refer 'text' of details.

HOTS Higher Order Thinking Skills & Brain Twisting

QUESTIONS WITH ANSWERS

Very Short Answer Questions *One mark each*

1. In which Kingdom of five kingdom classification, nuclear membrane is not present ?

Ans. Kingdom monera.

2. Name the kingdoms of three kingdom system classification.

Ans. Prostista, plantae and Animalia.

3. Who proposed the term Protista ?

Ans. Ernst Haeckel (1866).

4. Who gave the two kingdom system classification ?

Ans. Linnaeus (1758).

5. Which Methanogen is present in rumen of cattle ?

Ans. *Methanobacterium ruminatium.*

6. Name the anticoagulant present in bacterial endospore.

Ans. Dipicolinic acid.

7. Which bacteria are responsible for diseases :

(i) Cholera (ii) Tetanus

Ans. (i) **Cholera :** *Vibrio cholerae* (ii) **Tetanus :** *Clostridium tetani.*

8. What are auxospores ?

Ans. These are rejuvenile cells of diatoms which help in increasing their size to normal.

9. What is the alternative name of 'consumer decomposer protists' ?

Ans. Slime moulds.

10. Name the grooves present in dinoflagellates.

Ans. Longitudinal sulcus and circular cingulum (girdle, annulus)

11. Define coenocytic mycelium.

Ans. Multinucleate and aseptate hyphae are coenocytic.

12. Write the name of an aquatic fungus.

Ans. *Saprolegnia.*

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Short Answer Questions *Two marks each*

1. What is ascocarp?

Ans. Ascocarp is a fructification which form ascospores in asci in members of ascomycetes of fungi.

2. What is puffball?

Ans. It is an edible fungus bearing ball like basidiocarp which on maturity emits puff of spores e.g. *Lycoperdon.*

3. What is soredium?

Ans. Soredium is a propagule in lichens in which few algal cells are held together by a weft of fungal cells.

4. Name the fungus on rolling orange as green blue mould.

Ans. *Penicillium digitatum, P. italicum.*

5. What do you understand by terms lignocolous and corticolous?

Ans. **Lignocolous :** Growing on wood;

Corticolous : Growing on bark.

6. What is basidiocarp?

Ans. It is fructification of basidiomycetes, it bears basidiospores exogenously on basidia.

7. What is sclerotium?

Ans. Sclerotium is compact hyphal mass surrounded by thick covering which is meant for overcoming unfavourable conditions.

8. Define myxamoeba.

Ans. It is *Amoeba* like naked uninucleate cell of slime mould which can undergo independent feeding, growth and multiplication.

9. What is bioluminescence?

Ans. It is the emission of light by living beings e.g. *Peridinium.*

10. What do you understand by isochronic movement of cilia?

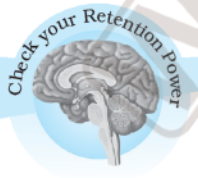
Ans. In this case, all cilia beat simultaneously.

Short Answer Questions *Three marks each*

1. Who proposed the five kingdom system of classification. Write the name of five kingdoms.
2. Write the characteristics of archaebacteria? How do these obtain food? How they are able to tolerate conditions like acidity and high temperature?
3. Why the members of class Deuteromycetes are considered the fungi imperfecti?
4. Discuss the living features of viruses.
5. Differentiate between ascocarp and basidiocarp.

Long Answer Questions *Five marks each*

1. Give an outline of five kingdom system of classification.
2. Write the general characteristics of dinoflagellates.
3. Which of the organisms are called 'jewels of plant world'? Elaborate your answer.
4. Differentiate between monera and protista.



QUICK MEMORY TEST

A. Say True or False

Write "True" or "False".

1. Charaka was the first to make a serious attempt to classify living things.
2. Prokaryotes are organisms without a nucleus.
3. Leeuwenhoek was the first to observe bacteria.
4. Actinomycetes belong to Monera.

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5. All autotrophs are Monerans.
6. In geological history complex organisms come after the simpler ones.

B. Complete the missing links

Fill the following sentences with suitable words :

1. .....egg is the largest eukaryotic cell.
2. Whittaker's five kingdoms are Monera,....., Fungi, Plantae and ..... .
3. Prokaryotes are without definite..... .
4. Yeasts are .....celled.
5. *Nepenthes* is an ..... plant.
6. The organisms which cannot manufacture their food due to absence of chlorophyll are called ..... .
7. *Chlamydomonas* is an unicellular green ..... .
8. Plants possess chlorophyll, hence are ..... .
9. Plants and animals both avoid ..... .

C. Choose the correct alternative

1. Cell wall is made up of peptidoglycan in **monera/protista.**
2. Heterocysts are present in **bacteria/cyanobacteria.**
3. *Puccinia graminis tritici* causes **black stem rust of wheat/loose smut of wheat.**
4. Lichens growing on soil, are called as **saxicolous/terricolous.**
5. **Basidiomycetes/Deuteromycetes** grow only by asexual spores.

D. Suitable words

Note the relationship between first two words and suggest a suitable word for the fourth place:

1. Bacteria : Prokaryote :: *Paramecium* : ..... .
2. Algae : Autotrophic :: Fungi : ..... .
3. Multicellular producers : Plants :: Multicellular decomposers : ..... .
4. Bacteria : Nucleoid :: Yeast : ..... .

E. Analogy Type Questions

Give the technical terms used for the following :

1. Remains of an organism of a former geological age.
2. Science of classification of organisms.
3. Evolutionary history of a group of organisms.
4. Organisms which synthesize their own food using chemical energy.

F. Reasoning Type Questions

Give reasons for the following statements :

1. Plants are large organisms.
2. Bacteria and blue-green algae are prokaryotes.
3. Fungi are heterotrophic.
4. Lichens are symbiotic.
5. Plants are producers.

Answers QUICK MEMORY TEST

A. Say True or False

1. False; **2.** True; **3.** True; **4.** False; **5.** True; **6.** True.

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B. Complete the missing links

1. Ostrich's **2.** Protista, Animalia **3.** nucleus **4.** one **5.** insectivorous **6.** heterotrophs **7.** alga **8.** autotrophic **9.** predators.

C. Choose the correct alternative

1. Monera; **2.** Cyanobacteria; **3.** Black stem rust of wheat; **4.** Terricolous; **5.** Deuteromycetes

D. Suitable words

1. Eukaryote; **2.** Heterotrophic; **3.** Fungi; **4.** Nucleus.

E. Analogy Type Questions

1. Fossil; **2.** Taxonomy; **3.** Phylogeny; **4.** Autotrophs.

F. Reasoning Type Questions

1. Due to presence of meristems, growth is unlimited throughout the life.
2. Bacteria and blue green lack well organised nucleus.
3. Fungi lack chlorophyll thus they are either parasite or saprophyte.
4. Algal partner of lichen provides food to fungal partner and fungal partner protects the algal member.
5. Plants show the process of photosynthesis

REVISION EXERCISES

Very Short Answer Questions

One mark each

1. Who introduced the term species?
2. Who observed bacteria for the first time?
3. Name the rain forest in India, which was recently saved from destruction.
4. In a traditional system followed so far, in how many kingdoms the living world was grouped?
5. Who made the earliest attempt to classify living beings?
6. Who wrote the books 'Species Plantarum' and 'Systema Naturae'?
7. What is progenote?
8. Who coined the term bacteria?
9. What is monera?
10. What are halophiles?
11. Which bacterium yields tetracycline?
12. What is denitrification?
13. Name a bacterium which yields insecticide.
14. What is transduction?
15. Expand PSP.
16. Name a colourless dinoflagellate.
17. Name the three groups of protistan algae.
18. Which type of organisms are included in Kingdom Protista.
19. Why the cyst is formed?
20. Which vector spreads kala-azar?
21. Name the vector of trypanosomiasis.
22. What is backpackers disease?
23. What is diatomite?
24. Which fungus was used to kill Roman Emperor Caesar?
25. Name the symbiotic associations in which fungi are participants.
26. Name a fungus which is found both in unicellular and mycelial states.
27. Define dolipore septum.

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28. Which fungus causes early blight of potato?
29. Name the causal organism of black stem rust of wheat.
30. What is morel?

ANSWERS

1. John Ray **2.** Leeuwenhoek **3.** Rain forests in Silent Valley of Kerala **4.** Two—plants and animals **5.** Aristotle **6.** Carolus Linnaeus; **7.** It is the early form of living beings from which all primitive and ancient organisms evolved; **8.** Ehrenberg (1828); **9.** Monera is the kingdom of all prokaryotes; **10.** Halophiles are archaebacteria that are found in habitats of high salinity and strong light intensity; **11.** *Streptomyces aureofaciens* **12.** Denitrification converts soil nitrate into gaseous nitrogen; **13.** *Bacillus thuringiensis;* **14.** Transduction is the transfer of genes from one bacterium to another through agency of virus; **15.** Paralytic Shell Fish Poisoning; **16.** *Noctiluca;* **17.** Dinoflagellates, diatoms and euglenoids; **18.** Unicellular and colonial eukaryotes; **19.** To tide over the unfavourable conditions; **20.** Blood sucking sand fly *(Phlebotomus);* **21.** Tsetse fly *(Glossina palpalis)* **22.** Giardiasis **23.** Diatomite represents the deposits of silica skeletons of diatoms; **24.** *Amanita caesaria;* **25.** Mycorrhiza, lichens; **26.** *Candida albicans*; **27.** In **dolipore septum** is one in which septum becomes barrel shaped around the central pore, it is the fusion of two sexual cells without the fusion of their nuclei; **28.** *Alternaria solani;* **29.** *Puccinia graminis tritici;* **30.** Morel is a fungus having a edible ascocarp of genus *Morchella.*

Short Answer Questions

Two marks each

1. Give names of 5 kingdoms proposed by Whittaker.
2. What are producers?
3. Into how many kingdoms, systematics has been divided from time to time?
4. What are lichens and mycorrhiza?
5. What are bacteriophages?
6. Write the names of kingdoms that include unicellular organisms and which comprise multicellular heterotrophic organisms.
7. What is progenote?
8. Highlight the criteria used for five kingdom system of classification.
9. What are chemoautotrophs?
10. What is transformation of bacteria?
11. What is lamellosome?
12. Which types of flagella are found in dinoflagellates?
13. What are the symptoms of amoeboid dysentery?
14. What are trichocysts?
15. What are sarcodines?
16. Define capillitium?
17. What is rhizomorph?
18. Define heterothallism?
19. Why some fungi are placed in fungi imperfecti?
20. What do you understand by holocarpic and eucarpic fungi?

ANSWERS

1. Monera, Protista, Fungi, Plantae and Animalia.
2. Organisms which form food are called producers.
3. In two 2, 3, 4 and 4 kingdoms.
4. Lichen is the dual composite organism made up of one algal and another fungal partner.
   Association of fungi and roots of higher plants is called **mycorrhiza.**
5. Virus which attack bacteria are called bacteriophages.
6. Unicellular organisms have been kept in Monera and Protista. Multicellular heterotroph organisms are kept under Fungi and Animalia.
7. It includes most primitive forms of life which appeared from an early stock known as progenote.
8. (i) Complexity of cell structure; (ii) Complexity of organism's body; (iii) Mode of obtaining nutrition.
9. **Chemoautotrophs** are bacteria which form organic matter from inorganic raw materials with the help of energy got from exergonic reactions.

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10. **Transformation** is the change in genetic constitution due to picking up of genes of dead and integrating the same in their nucleoids.
11. It is the membranous in growth of plasma membrane observed in cyanobacteria.
12. One narrow flagellum bearing mastigonemes and second flattened ribbon like but smooth in girdle or cingulum showing **heterokont** type of flagellation.
13. Acidic stools with blood mucus, membrane pieces and white charcot Leyden crystals. Abdominal pain.
14. Trichocysts are ejective in nature which are discharged on stimulation to form long thread for the tasks of offence, defence and adhesion.
15. Sarcodines are amoeboid protozoans which show pseudopodia for locomotion and feeding.
16. Capillitium represents the branching system of thread like structure formed inside the sporangium of acellular slime mould at the time of spore formation.
17. Rhizomorph is a compact structure, which is subterranean and cord like. It is a hyphal mass bearing a growing point for perennation.
18. It is the phenomenon of sexual reproduction in which fusing gametes are genetically different.
19. Due to absence of sexual reproduction.
20. **Holocarpic fungi :** In this vegetative structure is transformed into reproductive structure.

    Eucarpic fungi : In this case, reproductive phase is distinct from vegetative phase.

Short Answer Questions

Three marks each

1. What are the inadequacies of two kingdoms?
2. Write the identifying traits of Monera.
3. What are the distinguishing characters of kingdom fungi?
4. Discuss the drawbacks of two-kingdom system of classification.
5. Write briefly on **(a)** mode of life in Protista **(b)** nutrition in fungi.
6. Explain the distinguishing features of Animalia.
7. Describe the important characters of kingdom Plantae.
8. Compare the salient features of Monera with Protista.
9. Write salient features of viruses.
10. Draw well labelled diagrams of **(a)** Bacterial cell; **(b)** *Euglena.*
11. How ascomycetes are different from basidiomycetes?
12. Draw well labelled diagrams of : **(a)** Bacteriophage; **(b)** *Nostoc;* **(c)** TMV.
13. Discuss the locomotion of protists by different structures.
14. List the characteristics features of euglenoids.
15. Write the characteristics of archaebacteria.
16. What is mycorrhiza? How this association affects the organism.
17. Write any three differences between phycomycetes and ascomycetes.
18. What are the criteria used to classify fungi?

Long Answer Questions

Five marks each

1. Make an outline of the five-kingdom classification. What are the advantages and disadvantages of this classification?
2. What kinds of organisms are grouped under Protista? Would you consider this kingdom a natural one?
3. Give an account of early work in taxonomy.
4. Discuss different systems of classification.
5. Compare salient features of Monera and Protista.
6. Compare different types of fruiting bodies in fungi.

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7. Discuss reproduction in fungi.
8. Differentiate briefly characteristics of kingdom Plantae and Animalia.
9. Discuss the major group of protozoa.
10. Discuss the structure of a typical bacteria cell.
11. Differentiate between ascocarp and basidiocarp.
12. Write a brief account of reproduction in fungi.
13. What are heterocysts? Where these structures are present? Which characteristics make it possible for nitrogen fixation?
14. Differentiate between monera and protista.

COMPETITION FILE OBJECTIVE TYPE QUESTIONS

A. MULTIPLE CHOICE QUESTIONS (MCQs):

(From AIPMT & Other Competitive Examinations)

1. The prokaryotic cells are characterized by :
   (a) The presence of distinct nuclear membrane (b) Absence of chromatic materials
   (c) The presence of distinct chromosome (d) Absence of nuclear membrane ***(UP-CPMT 2009)***
2. Cell wall of bacteria and blue green algae is composed of :
   (a) Muramic acid (b) Chitin (c) Lipoprotein (d) Phospholipid ***(UP-CPMT 2009)***
3. Which one of the following is a symbiotic nitrogen fixer?
   (a) *Glomus* (b) *Azotobacter* (c) *Frankia* (d) *Azolla* ***(CBSE 2009)***
4. These organisms are fungus like in one phase of their life cycle and *Amoeba* like in another phase of their life cycle :
   (a) Diatoms (b) Slime molds (c) Dinoflagellates (d) Water molds ***(AIIMS 2009)***
5. In which of the following patterns of viral replication, viruses enter a cell, replicate and then cause the cell to burst, releasing new viruses?
   (a) Lytic (b) Lysogenic (c) Reprogenic (d) Both (a) and (b) ***(AIIMS 2009)***
6. Carolus Linnaeus is associated with :
   (a) Inheritance of acquired characters (b) Binomial nomenclature
   (c) Law of independent assortment (d) Law of limiting factors ***(AMU 2011)***
7. Which of the following is not a correct hierarchial order?
   (a) Class, family, genus (b) Phylum, order, family
   (c) Class, order, family (d) Family, order, class ***(AMU 2011)***
8. In the 5-Kingdom classification, the kingdom that includes the blue green algae, nitrogen fixing bacteria and methanogenic archaebacteria is :
   (a) Protista (b) Monera (c) Plantae (d) Fungi ***(AMU 2011)***
9. The basic unit of classification is :
   (a) Species (b) Genus (c) Family (d) Phylum ***(J&K 2011)***
10. The term taxonomy is introduced by :
    (a) De Candolle (b) Bentham and Hooker (c) Linnaeus (d) Huxley ***(J&K 2011)***
11. The framework system of classification in which various taxonomic categories are arranged in order of logical sequence is called :
    (a) Systematics (b) Classification (c) Hierarchy (d) Taxon ***(J&K 2011)***
12. Scientific study of diversity of organisms and their evolutionary relationships is called :
    (a) Morphology (b) Anatomy (c) Taxonomy (d) Systematics ***(J&K 2011)***

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13. According to five kingdom classification bacteria belong to :
(a) Protista (b) Monera (c) Plantae (d) Archaea ***(J&K 2011)***

14. A virus differs from bacterium, as it contains :
(a) A cell wall (b) Cytosol
(c) DNA as genetic material (d) DNA or RNA as genetic material with no ribosome ***(J&K 2011)***

15. Select the incorrect statements :
(A) Lower the taxon, more are the characteristics that the members within the taxon share.
(B) Order is the assemblage of genera which exhibit a few similar characters.
(C) Cat and dog are included in the same family Felidae.
(D) Binomial nomenclature was introduced by Carolus Linnaeus
(a) A, B and C (b) B, C and D (c) A and D
(d) C and D (e) B and C ***(Kerala 2011)***

16. Black rot of crucifers is caused by a:
(a) Fungus (b) Bacterium (c) Virus (d) None of these ***(AMU 2012)***

17. Pusa Komal variety of cow pea is resistant to disease:
(a) Hill bunt (b) White rust (c) Leaf curl (d) Bacterial blight ***(AMU 2012)***

18. Due to which of the following organisms, yield of rice is increased?
(a) *Sesbania* (b) *Bacillus popilliae* (c) *Anabaena* (d) *Bacillus subtilis* ***(BHU 2012)***

19. Which of the following kingdoms includes unicellular eukaryotes?
(a) Monera (b) Fungi (c) Protista (d) Plantae ***(BHU 2012)***

20. How many organisms in the list given below are autotrophs?
Lactobacillus, Nostoc, Chara, Nitrosomonas, Nitrobacter, Streptomyces, Saccharomyces, Trypanosoma, Porphyra, Wolffia.
(a) Four (b) Five (c) Six (d) Three ***(AIPMT 2012)***

21. Trichoderma is an example of which of the following?
(a) Phycomycetes (b) Zygomycetes (c) Deuteromycetes (d) Basidiomycetes ***(J&K 2012)***

22. Lichen is an association between:
(a) Fungi and bryophyte (b) Fungi and algae
(c) Algae and pteridophyte (d) Algae and bacteria ***(J&K 2012)***

23. Which class of fungi is called 'Fungi Imperfecti'?
(a) Ascomycetes (b) Deuteromycetes (c) Basidiomycetes (d) Zygomycetes ***(AFMC 2012)***

24. Which of the following is a pioneer in xerarch succession?
(a) Phytoplanktons (b) Lichens (c) Bryophytes
(d) Rooted hydrophytes (e) Sedges ***(Kerala 2012)***

25. Choose the wrong statements regarding bacterial cell:
(A) Glycocalyx is the outer most envelope in bacteria
(B) The glycocalyx could be a loose sheath called capsule
(C) The glycocalyx may be thick and tough called slime layer
(D) A special structure formed by the plasma membrane is called mesosome
(E) Small bristle like fibres sprouting out of the cell are called fimbriae
(a) A and C are wrong (b) A and B are wrong (c) B and C are wrong
(d) A and D are wrong (e) C and D are wrong ***(Kerala 2012)***

26. Match the following and choose the correct combination from the options given:

Column-I (Group)	**Column-II (Example)**
(A) Eubacteria	1. *Trichoderma*
(B) Dinoflagellates	2. *Albugo*
(C) Phycomycetes	3. *Gonyaulax*
(D) Deuteromycetes	4. *Anabaena*

(a) A-1; B-2; C-3; D-4 (b) A-2; B-3; C-4; D-1 (c) A-4; B-3; C-2; D-1
(d) A-3; B-4; C-1; D-2 (e) A-4; B-3; C-1; D-2 ***(Kerala 2012)***

27. Which of the following represent maximum number of species among global biodiversity?
(a) Lichens, (b) Fungi
(c) Mosses and ferns (d) Algae ***(NEET 2013)***

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28. Which group of animals belong to the same phylum?
(a) Earthworm, Pinworm, Tapeworm (b) Prawn, Scorpion, Locusta
(c) Sponge, Sea anemone, Starfish (d) Malarial parasite, *Amoeba*, Mosquito **(*NEET 2013*)**

29. The motile asexual reproductive unit is called:
(a) Zoospore (b) Aplanospore (c) Zygospore (d) Microspore **(*CHSE Cuttack 2013*)**

30. Select the **wrong statement:**
(a) Isogametes are similar in structure, function and behaviour
(b) Anisogametes differ either in structure, function or behaviour
(c) In Oomycetes female gamete is smaller and motile, while male gamete is larger and non-motile
(d) *Chlamydomonas* exhibits both isogamy and anisogamy and Fucus shows oogamy **(*CHSE Cuttack 2013*)**

31. Five kingdom system of classification suggested by R.H. Whittaker is not based on :
(a) Presence or absence of a well defined nucleus (b) Mode of reproduction
(c) Mode of nutrition (d) Complexity of body organisation **(*AIPMT 2014*)**

32. Archaebacteria differ from eubacteria in :
(a) Cell membrane structure (b) Mode of nutrition
(c) Cell shape (d) Mode of reproduction **(*AIPMT 2014*)**

33. The motile bacteria are able to move by :
(a) Fimbriae (b) Flagella (c) Cilia (d) Pili. **(*AIPMT 2014*)**

34. Viruses have :
(a) DNA enclosed in a protein coat (b) Prokaryotic nucleus
(c) Single chromosome (d) Both DNA and RNA. **(*AIPMT 2014*)**

35. Virus was first crystallised by:
(a) Beijerink (b) Stanley
(c) Ivanowsky (d) Leeuvenhoek **(*HPPMT 2012*)**

36. Correct the sequence of events in viral replication:
(i) Eclipse (ii) Maturation (iii) Adsorption (iv) Assembly
(v) Penetration (vi) Lysis
(a) i→ii→iii→iv→v→vi (b) ii→i→iii→iv→v→vi (d) iii→v→i→ii→iv→vi (e) iii→v→i→iv→ii→vi **(*WB 2012*)**

37. Which originated first:
(a) Prokaryotic cell (b) Eukaryotic cell
(c) Green algae (d) None of these **(*MPPMT 2013*)**

38. A virus can be considered living as it:
(a) Respires (b) Responds to touch
(c) Reproduces inside host (d) Can cause disease **(*JKCET 2013*)**

39. Which one has coiled RNA strand and capsomeres:
(a) Polio virus (b) Retro virus (c) Tabacco mosaic virus (d) Measles virus **(*CBSE 2014*)**

40. Choose the wrong statement :
(a) Morels and truffles are poisonous mushrooms.
(b) Yeast is unicellular and useful in fermentation.
(c) *Penicillium* is multicellular and produces antibiotics.
(d) *Neurospora* is used in the study of biochemical genetics. **(*AIPMT 2015*)**

41. Chitin is a/an :
(a) Amino acid (b) Polysaccharide
(c) Protein (d) Oligosaccharide **(*Bihar CECE 2014*)**

42. It employs both intracellular and extracellular digestion :
(a) *Hydra* (b) *Aurelia* (c) *Amoeba* (d) *Planaria* **(*Bihar CECE 2015*)**

43. Which part of the cell contains N–acetyl glucosamine?
(a) Cell envelope (b) Cell wall (c) Nucleus (d) Ribosomes **(*Bihar CECE 2015*)**

44. Which one is a holophytic protazoa?
(a) *Euglena* (b) *Amoeba*
(c) *Monocystis* (d) *Giardia* **(*Bihar CECE 2015*)**

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45. What is the range of length of sponges?
(a) 1 mm - 10 mm (b) 1 cm - 1 metre
(c) 1 mm - 100 mm (d) 1 metre - 10 metre **(*Bihar CECE 2015*)**

46. Poterion is an example of :
(a) Protozoa (b) Porifera
(c) Cnidaria (d) Ctenophora **(*Bihar CECE 2015*)**

47. This is not a cnidarian :
(a) *Obelia* (b) Jelly fish
(c) Sea anemone (d) *Beroe* **(*Bihar CECE 2015*)**

48. Match the pairs of diseases and pathogens :

Column-I	**Column-II**
1. Malaria	a. *Wuchereria bancrofti*
2. Filariasis	b. Helminth
3. Typhoid	c. *Plasmodium falciparum*
4. Schistosomiasis	d. *Salmonella typhi*

(a) 1-c, 2-b, 3-a, 4-d (b) 1-d, 2-a, 3-b, 4-c
(c) 1-a, 2-b, 3-c, 4-d (d) 1-c, 2-a, 3-d, 4-b **(*Maharastra CET 2015*)**

49. Considering mode of asexual reproduction, match the Column I with Column II and select the correct option :

Column-I	**Column-II**
A. Yeast	i. Fragmentation
B. *Penicillium*	ii. Zoospores
C. Filamentous	iii. Budding
D. *Chlamydomonas*	iv. Conidia

(a) A-iii, B-iv, C-i, D-ii (b) A-ii, B-iii, C-i, D-iv
(c) A-iv, B-iii, C-ii, D-i (d) A-iii, B-ii, C-i, D-iv **(*Maharastra CET 2015*)**

50. The group of fungi that are called fungi imperfecti are :
(a) Ascomycetes (b) Zygomycetes
(c) Deuteromycetes (d) Basidiomycetes **(*COMEDK 2015*)**

51. Which one of the following statements is wrong?
(a) Cyanobacteria are also called blue-green algae (b) Golden algae are also called desmids
(c) Eubacteria are also called false bacteria (d) Phycomycetes are also called algal fungi **(*NEET-I 2016*)**

52. Following are the two statements regarding the origin of life:
1. The earliest organisms that appeared on the earth were non-green and presumably anaerobes
2. The first autotrophic organisms were the chemoautotrophs that never released oxygen
(a) 1 is correct but 2 is false (b) 2 is correct but 1 is false
(c) Both 1 and 2 are correct (d) Both 1 and 2 are false **(*NEET-1-2016*)**

53. Select the mismatch :
(a) *Rhodospirillum* – Mycorrhiza (b) *Anabaena* – Nitrogen fixer
(c) *Rhizobium* – Alfalfa (d) *Frankia* – Alnus **(*NEET-2017*)**

54. Which among the following is ***not*** a prokaryote?
(a) *Mycobacterium* (b) *Nostoc*
(c) *Saccharomyces* (d) *Oscillatoria* **(*NEET-2018*)**

ANSWERS

1. (d);	**2.** (a);	**3.** (c);	**4.** (b);	**5.** (a);	**6.** (b);	**7.** (d);	**8.** (b);	**9.** (a);	**10.** (c);
11. (c);	**12.** (d);	**13.** (b);	**14.** (c);	**15.** (e);	**16.** (b);	**17.** (d);	**18.** (c);	**19.** (c);	**20.** (a);
21. (c);	**22.** (b);	**23.** (b);	**24.** (b);	**25.** (c);	**26.** (c)	**27.** (b);	**28.** (b);	**29.** (a);	**30.** (c);
31. (a);	**32.** (a);	**33.** (b);	**34.** (a)	**35.** (b);	**36.** (c);	**37.** (a);	**38.** (c);	**39.** (c);	**40.** (a);
41. (b);	**42.** (a);	**43.** (b);	**44.** (a);	**45.** (b);	**46.** (b)	**47.** (d);	**48.** (d);	**49.** (a);	**50.** (c);
51. (c);	**52.** (c);	**53.** (a);	**54.** (c).						

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B. CBSE - PMT (MAIN EXAMINATION) QUESTIONS :

1. **Differentiate between Monera and Protista based upon the following characters :**
   (a) Chemical nature of cell wall
   (b) Location of respiratory apparatus
   (c) Types of cytoplasmic ribosome
   (d) Genetic material
   (e) Location of extrachromosomal DNA.

Ans.

Character	Monera	Protista
(a) Chemical nature of cell wall	Made up of peptidoglycan.	Made up of cellulose.
(b) Location of respiratory apparatus	Presence of respiratory membranes.	Presence of mitochondria.
(c) Types of cytoplasmic ribosome	70S	Cytoplasmic ribosomes; 80S Organelle ribosomes : 70S
(d) Genetic material	Prokaryotic, naked circular DNA	Eukaryotic, Linear DNA in nucleus.
(e) Location of extra-chromosomal DNA	Present in cytoplasm in form of sex plasmid	Present in organelles like mitochondria and chloroplasts.

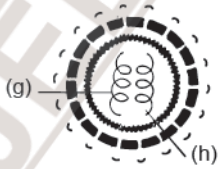
(CBSE 2006)

2. **Differentiate between slime mould and fungi.**

Ans.

Slime mould	Fungi
Slime moulds are saprophytic protists.	Fungi constitute a kingdom of heterotrophic organisms which can be saprophytes, parasites or symbiont.
Spore have a cell wall of cellulose, chitin is absent.	Chitin is present in cell wall.

3. **Identify the given diagram and also write down its two methods of transmission and label (g) or (h) also.**



Ans. Human Immunodeficiency Virus (HIV). Two methods of transmission of HIV are :
(a) Use of non-sterile needles.
(b) During sexual intercourse, from an infected partner to a healthy partner.
(g) is single-stranded RNA and (h) is reverse transcriptase.

C. MATCHING TYPE QUESTIONS :

Match the terms in Column A with suitable terms in Column B :

Column A	Column B
(i) Cyanobacteria	(a) Symbiosis
(ii) Diatoms	(b) Phytoplankton
(iii) Protozoa	(c) Fungi
(iv) Lichen	(d) Blue-green algae
	(e) Holozoic nutrition

ANSWERS

(i) (d); **(ii)** (b); **(iii)** (e); **(iv)** (a).

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D. ASSERTION TYPE QUESTIONS :

These questions consist of two statements each, printed as *Assertion* and *Reason*. While answering these questions, you are required to choose any one of the following four responses.
A. If both *Assertion* and *Reason* are true and the *Reason* is a correct explanation of the *Assertion*.
B. If both *Assertion* and *Reason* are true but *Reason* is not a correct explanation of the *Assertion*.
C. If *Assertion* is ture but the *Reason* is false.
D. If both *Assertion* and *Reason* are false.

1. **Assertion :** Viruses are not included in any system of classification.
Reason. Viruses are non-living but develop living characters like multiplication etc. when they come in contact with suitable host.
A **B** **C** **D**
2. **Assertion.** Plants manufacture food only during the day time.
Reason. During day time, metabolism is high.
A **B** **C** **D**
3. **Assertion.** Bacteriophages are a type of bacteria.
Reason. Bacteria are unicellular, eukaryotic organisms.
A **B** **C** **D**
4. **Assertion**. In Monera kingdom, cell wall bears unique polymers of amino sugars and amino acids called peptidoglycans.
Reason. It is a derivative of phospholipids.
A **B** **C** **D**
5. **Assertion**. The photosynthetic, floating protists are collectively called **phytoplanktons.**
Reason. The free floating ,holozoic protozoans are collectively termed **zooplanktons**.
A **B** **C** **D**
6. **Assertion**. Ernst Haeckel has classified living beings into three kingdoms.
Reason. The three kingdoms are Protista, Plantae and Animalia.
A **B** **C** **D**
7. **Assertion**. The fungi are widespread in distribution and they even live on inside other plants and animals.
Reason. Fungi are able to grow anywhere on land, water or other organisms because they have a variety of pigments including chlorophyll, carotenoids, fucoxanthin and phycoerythrin.
A **B** **C** **D** ***(AIIMS 2005)***

ANSWERS

1. A; **2.** C; **3.** D; **4.** C; **5.** B; **6.** A; **7.** C.

E. ADDITIONAL MULTIPLE CHOICE QUESTIONS :

Choose the correct answer :

1. The system of classification which employs numerical method to evaluate the similarities and differences between the species is known as :
(a) Bio-systematics (b) Cyto-taxonomy (c) Phenetics (d) Chemotaxonomy
2. *Thermococcus*, *Methanococcus* and *Methanobacterium* exemplify :
(a) Bacteria whose DNA is relaxed or positively supercoiled but which have a cytoskeleton as well as mitochondria
(b) Bacteria that contain a cytoskeleton and ribosomes
(c) Archaebacteria that contain protein homologous to eukaryotic core histones
(d) Archaebacteria that lack any histones resembling those found in eukaryotes but whose DNA is negatively supercoiled
3. New systematics introduced by Sir Julian Huxley is also called :
(a) Phenetics (b) Cladistics (c) Biosystematics (d) Numerical taxonomy
4. Which of the following is an edible 'fungi'?
(a) *Mucor* (b) *Penicillium* (c) *Agaricus* (d) *Rhizopus*
5. Bacteria are considered plant, because :
(a) Are green in colour (b) Have rigid cell wall (c) Have chlorophyll (d) Have stomata
6. Viruses possess :
(a) DNA only (b) Nucleic acid, DNA or RNA
(c) Protein only (d) Nucleic acid and protein

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7. The thalloid body of a slime mould (Myxomycetes) is known as :
(a) Protonema (b) *Plasmodium* (c) Fruiting body (d) Mycelium
8. Huxley is father of :
(a) Classical taxonomy (b) Artificial taxonomy (c) Neo-taxonomy (d) Adansonian taxonomy
9. Systema Naturae is written by :
(a) Linnaeus (b) Aristotle (c) Hippocrates (d) Darwin
10. Binomial nomenclature was first issued in :
(a) Systema Naturae (b) Genera Plantarium (c) Genera Animalium (d) Historia Plantarium
11. The term bacteria was coined by :
(a) Leeuwenhoek (b) Louis Pasteur (c) Robert Koch (d) Ehrenberg
12. The non-living characteristics of viruses is :
(a) Ability to multiply only in the host (b) Ability to cause disease in the host
(c) Ability to undergo mutation (d) Ability to be crystallised
13. The kingdom of prokaryotes is :
(a) Protista (b) Monera (c) Fungi (d) Plantae
14. Systematic botany means :
(a) System analysis (b) Systematic arrangement of organs of plants
(c) Systematic study of plants dealing with identification (d) Naming and classification study of plants in gardens
15. Which of the following statements is false?
(a) TMV has a double stranded RNA molecule (b) Most plant viruses are RNA viruses
(c) Bacteriophage has a double stranded DNA molecule (d) Most animal viruses are DNA viruses
16. A phylum common to unicellular animals and plants is :
(a) Monera (b) Plantae (c) Fungi (d) Protista
17. An example of symbiotic bacteria :
(a) *Erwinia amylovora* (b) *Rhizobium leguminosarum*
(c) *Xanthomonas campestris* (d) *Agrobacterium tumefaciens*
18. Which one of the following are intracellular obligate parasites?
(a) Bacteria (b) Viruses
(c) Slime moulds (d) Blue green algae
19. Phylum protozoa is classified on the basis of :
(a) Mode of reproduction (b) Locomotory organelles (c) Mode of nutrition (d) None of these
20. Natural system of classification was given by :
(a) Carolus Linnaeus (b) George Bentham and Joseph Dalton Hooker
(c) Hutchinson (d) Ernest Haeckel

ANSWERS

1. (c);	2. (c);	3. (c);	4. (c);	5. (b);	6. (d);	7. (b);	8. (c);	9. (a);	10. (a);
11. (d);	12. (d);	13. (b);	14. (c);	15. (a);	16. (d);	17. (b);	18. (b);	19. (b);	20. (b).

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Chapter Practice Test

Time Allowed : 1:30 Hours *Maximum Marks : 35*

1. Are chemosynthetic bacteria autotrophic or heterotrophic? (1)
2. How the saprophytic basidiomycetes are able to decompose plant matter? (1)
3. What is dolipore? (1)
4. What are bracket fungi? (1)
5. Which protistans show flagellar locomotion? (1)
6. Why *Trypanosoma* has been placed in Kingdom Protista? (2)
7. What are chrysophytes? Why they are considered as the chief producers in the ocean? (2)
8. What is capsid? How it is useful for viruses? (2)
9. Name the fungus which is in biological control of other fungi. How it is harmful to humans? (2)
10. Name the causal organisms of :
    (a) Early blight (b) Red rot of sugarcane (c) Wilt (d) Brown leaf spot of rice (2)
11. Explain the structure of bacteriophage. (3)
12. Discuss the methods of reproduction in fungi. (3)
13. Discuss how classification system has undergone several changes over a period of time. (3)
14. Why the taxonomy felt the need of modern taxonomy over old taxonomy? (3)
15. Differentiate between monera and protista. (3)
16. Give a brief account of viruses with respect to their structure and nature of genetic material. Write the name of any three viral diseases. (5)

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To check your performance, see ANSWERS TO CHAPTER PRACTICE TEST at the end of Part I of the book.

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CHAPTER 3

PLANT KINGDOM

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CHAPTER PRACTICE TEST 62

SYSTEMS OF CLASSIFICATION

All the systems of classification starting from that of Aristotle or Theophrastus to twentieth century fall into two categories : (i) **Historical classifications** and (ii) **Modern classifications.** The **historical classifications** started from the period of Aristotle and Theophrastus ending up to de Condolle. **Modern classifications** include all those systems of classification started from Bentham and Hooker to the systems proposed till date. Both historical and modern systems of classification can be divided into four types of classification systems :

1. Artificial classification
2. Natural classification
3. Phylogenetic classification
4. Phenetic classification.

1. Artificial classification

In **artificial systems,** the plants are classified according to convenience, mainly for an aid to identification, using a few easily recognizable characters. It is called artificial simply because it uses for classification few easy observable characters such as habit, colour, number, morphology etc. The artificial systems are not in current use because of several drawbacks. The most important **drawback** is that plants closely related to each other may find a place in widely separated groups and quite different plants may occupy the same group. All of the artificial systems are of, now, historical importance. Out of several artificial systems, the best is of **Linnaeus** published in 1735.

2. Natural classification

The **natural systems of classification** were based on form **relationships** (related affinities taking into consideration all the important characters of the plants). This system includes not only external features but also internal features like ultra-structure, anatomy, embryology, phytochemistry etc. These systems reflected men's understanding of the nature at that time. The plants showing the correlation of characters in common were placed together. Bernard, de Jussieu and de Condolle made significant contributions to this system. The natural systems remained dominant till modern theories of evolution were known. The last and most important natural systems remained dominant till modern theories of evolution were known. The system is being followed by most of herbaria. The last and most important natural system of classification was given by **George Bentham** and **Joseph Dalton Hooker** (1862-83).

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Table 1. Differences between natural and artificial systems of classification.

Character	Natural System	Artificial System
1. **Number of characters**	Uses number of characters	Uses only one or few characters
2. **Relation**	Characters not related to habit or habitat	Usually related to habit and habitat
3. **Stability**	Characters are stable	Liable to change with change in environment.
4. **Used characters**	Like morphology, anatomy, cytology, molecular biology and genetics	Uses traits like morphology and reproduction
5. **Analogy**	Does not use analogy	Uses analogy for the purpose of grouping
6. **Homology**	Brings out homology.	It does not study homology.
7. **Placing of related organisms**	Usually placed in same group	Usually found in different groups
8. **Relationship**	Gives some idea about natural and phylogenetic relationships.	Does not give any idea about natural and phylogenetic relationships.

3. Phylogenetic classification

The **phylogenetic systems** are based on the **evolutionary** and genetic affinities of the plants. These systems appeared after the publication of "Origin of Species" by Darwin in 1859 (The Bentham and Hooker's system, although, appeared after Darwin's theory of evolution, but was based on pre-evolutionary concept). The systems of this group have attempted to classify plants from the simple to complex ones establishing the genetic and ancestral relationship. These systems, however, are not "truely phylogenetic", because of lack of continuity in evolutionary records. So, at present, the plants are mostly classified partly on natural and partly on phylogenetic basis. Some of the important phylogenetic systems are those given by **Engler** (1886), **Hutchinson** (1926) and modern systems those of **Takhtajan** (1967) and **Cronquist** (1968).

4. Phenetic classification

Recently, few additional criteria and methodologies are employed in classifying organisms to avoid the difficulties of establishing evolutionary relationships which are difficult and controversial particularly if there is no fossil evidences.

(a) Numerical taxonomy or phenetics. It uses the numerical techniques for evolution of similarities and differences between the species. This is done with the help of calculators and computers. He re all possible characters are used for comparison. All characters are given equal importance and weightage at the time of analysis. Here data is statistical and objectively defined and takes into consideration many characteristics. Here codes are assigned to them on computers like plus (+) and minus (–) or data not available (⊖).

(b) Cladistic (phylogenetic) taxonomy. It classifies living beings into historical order in which evolutionary branches arose. Here the taxonomy affinity is based on evolutionary as well as genetic relationship amongst organisms besides morphology. From this origin of **new systematics** (Sir Julian Huxley 1940) or **biosystematics** took place. Similar characters that arose from common ancestor of an entire group are called **ancestral characters.** The similar character that arose within distinct group are termed as **derived characters.** In **Cladistic** method only shared derived characters are considered informative.

(c) Cytotaxonomy. It provides cytological information of cell, its chromosome number, structure etc. It also involves the behaviour of chromosomes at the time of classification for the purpose of classification. Few examples related to cytotaxonomy are :

(i) In every species number of chromosomes is constant. Man has the diploid chromosome number of 46 and potato has 48.

(ii) Size of different chromosomes in different herbaceous plants have been found to be larger than woody plants.

(iii) Relationship among different species has become clear due to mode of pairing of chromosomes during meiosis.

Table 2. Differences between natural and phylogenetic systems.

Character	Natural System	Phylogenetic System
1. **Type of characters**	Based on number of constant characters.	Based on constant features and evolutionary sequences.
2. **Results**	Brings out similarities and differences amongst organisms. It helps them to arrange them in groups and subgroups.	Brings out sequences in which taxa evolved.
3. **Role of fossils**	Of little significance.	Fossils provide vital information
4. **Practical utility**	More practical utility for easy identification.	Lesser practical utility being the evolution as slow process.

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Table 3. Differences between Cytotaxonomy and Chemotaxonomy.

Characters	Cytotaxonomy	Chemotaxonomy
1. Basis	Based on cellular characters.	Based on chemical constitution.
2. Relationship	Related to genetic resemblances and changes.	Related to expression of genetic resemblances and changes.
3. Information	Provides information about relationship and evolution.	Provides information about chemicals, proteins and nucleic acids thus providing data about relationship and evolution.

(d) Chemotaxonomy. This type of taxonomy utilises the chemical constituents of plants. Such characters like fragrance and taste have been found to be stable and do not change easily. Other such interesting characters of taxonomic value are presence of calcium oxalate crystals (raphides) and sulphur containing compounds in family Cruciferae. Many similarities and relationships have been put forth by studies on DNA sequencing and chemical nature of proteins. Study of chemical characters have greatly further helped the taxonomists in gathering possible relationships and statistical evolution of taxonomic value.

PLANT KINGDOM—INTRODUCTION

Some plants are **aquatic**, usually marine as red, brown and green algae. Second category is of **land plants**. Land plants are further divided into following divisions:

(a) Thallophyta. It embraces the most primitive and simple of all plants. The plant body is either unicellular or multicellular thallus. Thallophyta is traditionally divided into four groups : **Algae, Fungi, Bacteria** and **Lichens.**

(b) Bryophytes. They constitute liverworts and mosses and are found in moist, shady and cold places.

(c) Tracheophytes. Vascular plants like **pteridophytes, spermatophytes (gymnosperms** and **angiosperms**) are included in this division. Tracheophytes are far more abundant and important and will occupy most of our attention.

Cryptogams include three main groups :

(i) Thallophyta (ii) Bryophyta

(iii) Pteridophyta

Cryptogams are flowerless or seedless plants. Flowering or seed bearing plants have been called as **Spermatophyta** or **Phanerogams.** Spermatophytes are further divided into two sub-groups:

(i) Gymnospermae (with naked seeds)

(ii) Angiospermae (with covered seeds).

Thallophyta where the plants do not form embryos include Algae, Fungi, Bacteria and Lichens.

According to one system of classification, Bryophyta, Pteridophyta and Spermatophyta can be included in **Embryophyta** (Plants forming embryos).

Angiosperms have been divided into two classes:

(i) Dicotyledons (with two cotyledons).

(ii) Monocotyledons (with one cotyledon).

The kingdom Plantae is classified into : Algae, Bryophytes, Pteridophytes (seedless vascular plants), Gymnosperms, Angiosperms.

ALGAE (e.g. *Spirogyra, Ulothrix*)

They show the following characters :

(a) They contain chlorophyll.

(b) They are autotrophic.

(c) They are aquatic or semi-aquatic.

(d) The sex organs are usually unicellular and non-jacketed.

(e) Sporophytic and gametophytic stages are independent.

(f) Vascular tissue absent.

(g) Dominating plant phase is gametophyte.

BRYOPHYTA (e.g. *Marchantia, Funaria*)

Bryophytes show the following important characters:

(a) The dominating phase of life cycle is gametophyte.

(b) The plant body is not differentiated into roots, stem and leaves.

(c) Absorbing and anchoring organs are rhizoids.

(d) Vascular tissue and mechanical tissue is absent.

(e) Fertilization is internal.

(f) Sexual reproduction is of oogamous type.

(g) Sex organs are multicellular and jacketed.

(h) Sporophytic phase is lengthy.

(i) Formation of sporogonium takes place.

(j) Heterologous and haplodiplontic type of alternation of generations occur.

PTERIDOPHYTA (e.g. *Selaginella, Dryopteris*)

These are vascular cryptogams.

The distinguishing characters are :

(a) The dominating plant phase is sporophyte.

(b) Plant body is differentiated into roots, stem and leaves.

(c) The branching is never axillary.

(d) Vascular tissue makes its appearance.

(e) Pteridophytes are homosporous or heterosporous.

(f) Sexual reproduction is of oogamous type.

(g) The antheridium is sessile and reduced in size.

(h) Heterologous and diplohaplontic type of alternation of generations is present.

(i) They produce spores inside sporangia on leaves.

GYMNOSPERMAE (e.g. *Pinus, Cycas*)

Key characters are as under :

(a) The seeds are exposed or naked.

(b) Life cycle is heterosporous.

(c) Better adaptation for land habit.

(d) Fertilization is siphonogamous *i.e.* by pollen tube.

(e) Due to development of cambium, they show secondary growth.

(f) Seeds are borne on structures called cones.

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ANGIOSPERMAE

(a) They produce flowers.
(b) Seeds are covered.
(c) Process of double fertilization is present.
(d) The ovary ripens into fruit which contains the seeds.
(e) Reduced gametophytic phase is present.

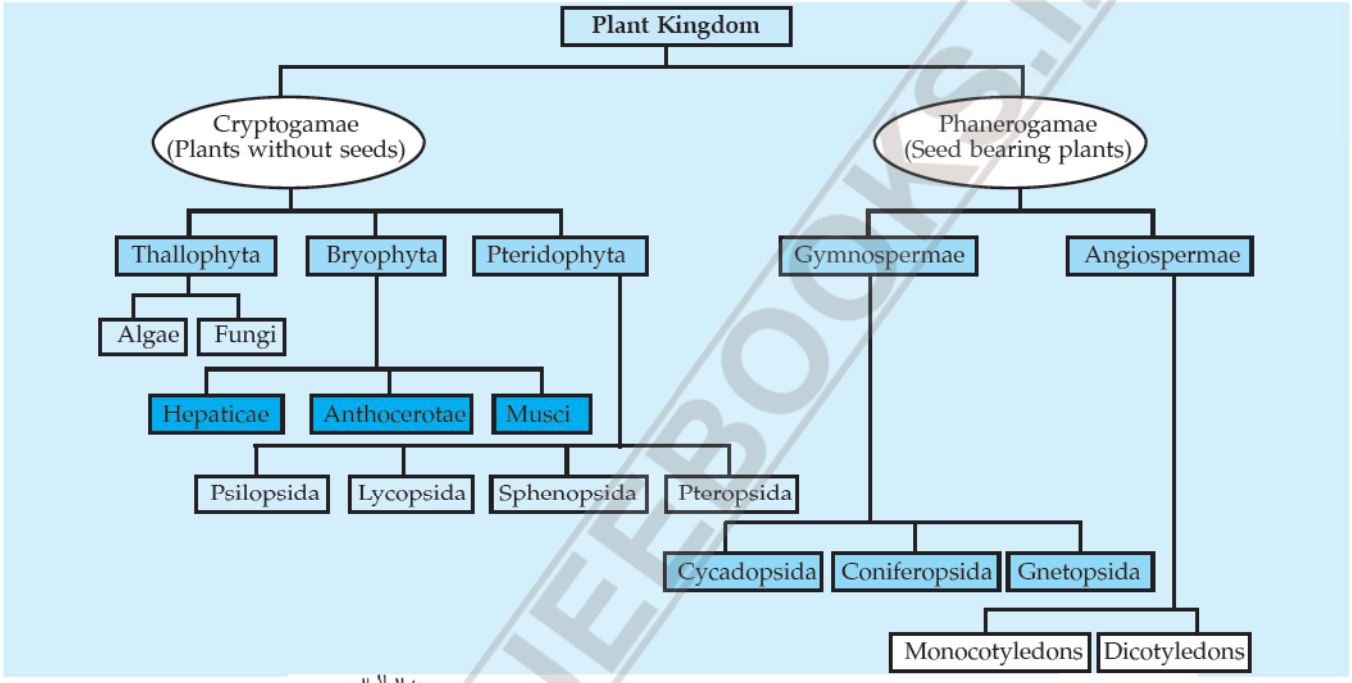
ALGAE

Algae contains near about 18,000 genera with 29,000 species. All of them being a thallus lack a differentiation of body into true roots, stem and leaves.

Algae possess chlorophyll, although many of them particularly red and brown algae are not green in colour, because presence of other pigments mask the green colour of chlorophyll.

Size and form. There is great variation of size from small unicellular microscopic organisms (*Chlamydomonas*) to kelps (brown algae) attaining height up to 60 metres. The body of multicellular algae range from small colonial (*Volvox*) to largest like *Macrocystis* having the length of several hundred feet. Few types are filamentous.

CLASSIFICATION OF PLANTS



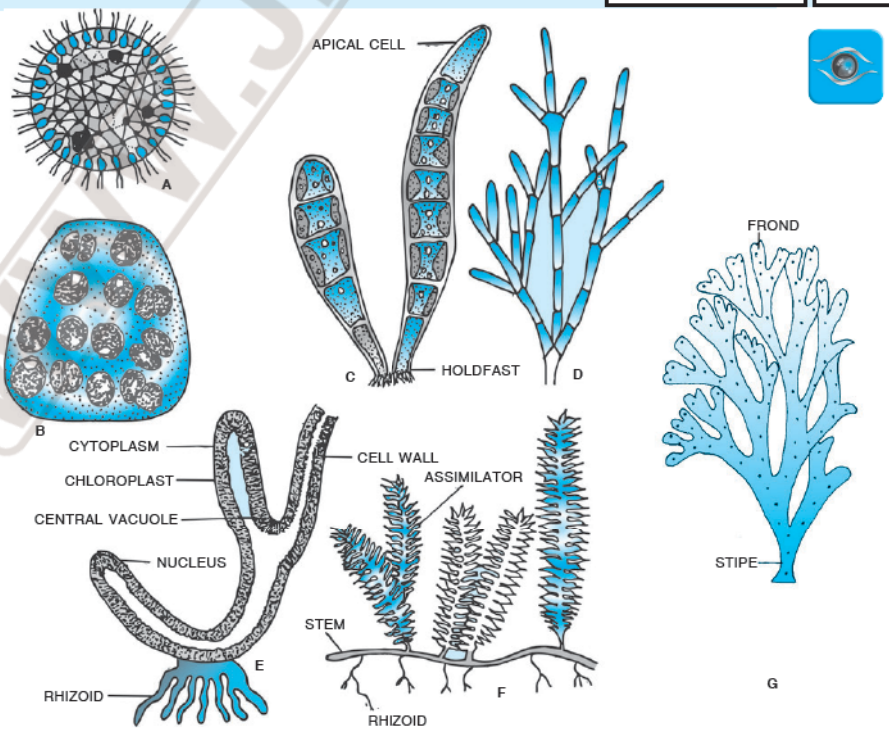


Fig. 1. Organisation of thallus in Algae.
A. *Volvox*; **B.** *Tetraspora*; **C.** *Ulothrix*; **D.** *Cladophora*; **E.** *Vaucheria*; **F.** *Caulerpa*; **G.** *Dictyota*.

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Filamentous forms may be branched (*Cladophora*) or unbranched (*Spirogyra, Zygnema*). Filamentous form may be free floating or attached with substratum by holdfast or hapteron. Sometimes thallus is multinucleate but not divided into cells (except at the time of reproduction). Such siphonaceous forms are present in algae like *Vaucheria*.

Cells in thalli may become specialised also. They bear lamina (leaf-like blade). Sometimes branches are attached to stem like part called **stipe** and attached with **holdfast.**

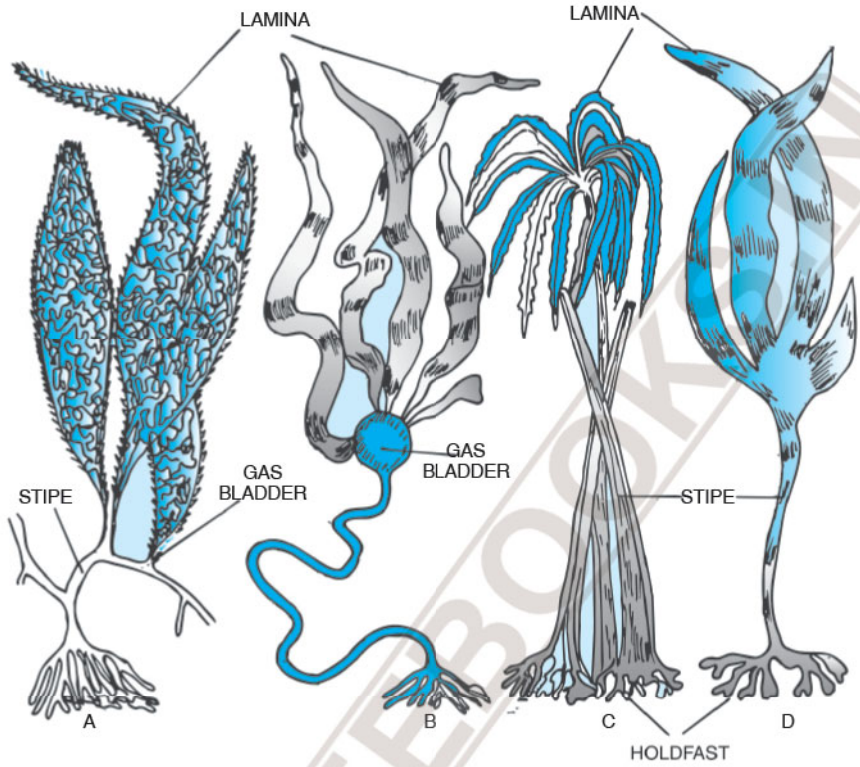

Fig. 2. Organisation of thallus in Algae **A.** *Macrocystis;* **B.** *Nereocystis;* **C.** *Postelsia;* **D.** *Laminaria.*

Table 4. Pigments, Storage food and Complexity of thallus in kingdom plantae.

Kingdom	Group	Photosynthetic pigments		Storage food	Complexity of structure
		Chlorophyll	Other pigments		
Plantae	Red algae	*a* + *d*	Phycobilins (phycoerythrin & phycocyanin)	Floridean starch	Unicellular to multicellular
	Brown algae	*a* + *c*	Special carotenoids fucoxanthin	Lipid laminarin, Mannitol	Multicellular
	Green algae	*a*+*b*	β-Carotene and other carotenoids	Starch	Unicellular to multi-cellular

Table 5. Diagnostic features of important groups of algae.

Division	Storage product	Flagellation	Photosynthetic apparatus	Cell wall
Chlorophyta (Green algae)	Starch	1, 2 or upto (or more), equal, anterior, acrone-matic, smooth, apical	Chloroplasts with 2-6 thylakoids in a band pyrenoids with starch sheath	Cellulosic
Phaeophyta (Brown algae)	Lamanarin, mannitol and leucosin	2, unequal lateral; 1 acronematic and 1 pantonematic	Like xanthophyta, pyrenoids naked and projecting	Cellulosic with alginic and fucinic acids
Rhodophyta (Red algae)	Floridean starch	Absent	Chromatophores with single and widely separated thylakoids, naked pyrenoid	Non-cellulosic polysac-charides or with xylan galactose and xylose, occasionally cellulosic

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Habitat. Regarding habitat, algae show great variation. They are found in moist places, on tree trunks, in still and running waters, on flower pots and a number of them are marine. Some algae like *Zygnema*, *Oedogonium* inhabit still water. *Cladophora* is primarily a running water genus. Some members of red algae like *Batrachospermum* are also found in freshwater. Few algae are marine *i.e.* found in sea water. Most of the brown and red algae are marine. Some siphonaceous algae are also found in sea.

Adaptation of algae for water

Adaptation of algae for water. Aquatic algae are well adapted to survive in water as :

1. Algae are continuously supplied by nutrients by surrounding water.

2. Because they remain surrounded by water, they do not need vascular tissue.

3. Water keeps the algae buoyant. They do not require mechanical tissue like sclerenchyma etc. as in higher woody plants to stand erect.

4. Due to their flexible nature, tides and severe water currents fail to tear and injure them.

5. Water is suitable medium for the fusion of gametes during sexual reproduction. Aquatic conditions also help in dispersal of asexual spores.

Pigments in algae. Chlorophyll (green pigment) is found in all members of algae. However, in many green colour is masked by other pigments. For example, fucoxanthin and phycophein (special carotenoids) are dominant in brown algae. Similarly phycoerythrin and phycocyanin, red and blue-green pigments are the main pigments in blue-green and red algae.

RED ALGAE (RHODOPHYCEAE)

Number. there are about 5,254 species related to 831 genera (Dixon, 1973) of red algae, out of which 348 species belonging to 117 genera are recorded from India (Sharma and Khan, 1980).

Habitat. They are marine, occur in almost all oceans.

Appearance. They are the most showy of all the seaweeds and are graceful being lace-like.

Size. Their size ranges from unicellular to half a metre in length.

Pigments. The photosynthetic pigments are

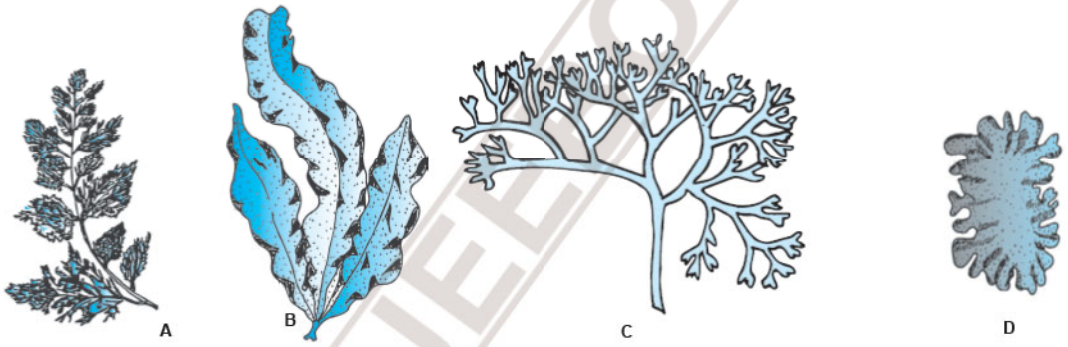

Fig. 3. Types of red algae. **A.** feathery thallus of *Polysiphonia* ; **B.** leaf-like thallus of *Grinellia* ; **C.** branching thallus of *Chondrus* ; **D.** *Porphyra*.

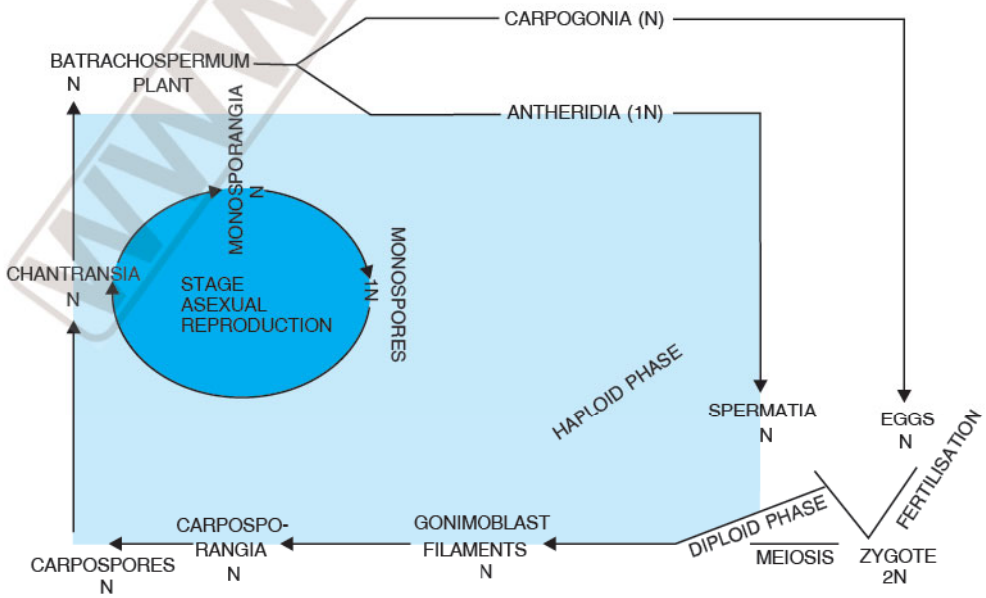

Fig. 4. Graphic representation of the life cycle of *Batrachospermum* (a red alga).

bilioproteins (phycoerythrin and phycocyanin) along with chlorophyll and carotenoid tetraxanthin. Pigments are same as in cyanobacteria but in cyanobacteria, phycocyanin is found in more quantity.

Red pigment absorbs the blue-green wavelength in visible spectrum easily.

Colour. The red algae owe their name to the characteristic red colour of vast majority of the group. All, however, are not red in colour.

In greater depth of sea, red algae exhibit more redness due to more quantity of pigment phycoerythrin. Blue-green wavelength of sunlight reaching the maximum depth of sea is absorbed by phycobilin pigments. However, in shallower regions of sea red algae exhibit green colour due to more quantity of chlorophyll. Red algae due to the nature of their pigments and their light absorbing capacity are able to grow in depth of sea, where other green plants fail to appear.

Lacier. Rhodophytes being **lacier** and more delicate than sturdy brown algae are adapted to withstand pounding surf, but in deeper water red algae are not so much subjected to wave action.

Coral atolls. The coralline red algae accumulate calcium from the sea water and deposit it in their bodies as calcium carbonate. These coralline algae play an important role in the formation of coral atolls than coral animals.

Storage product. The reserve food material is usually **floridean starch** and **galactoside floridoside** outside the chromatophore in cytoplasm.

Flagella. Flagellated cells are lacking altogether in red algae.

Cell wall. Cell wall in red algae is made up of **polysulphate esters** along with pectic materials. Cellulose is also present in cell wall.

Reproduction. Reproduction occurs by both sexual and asexual methods. The spores are non-motile.

Sexual reproduction is highly specialised. Male gametes are non-motile and called **spermatia**.

Spermatia are carried by water current to elongated tip **trichogyne** of female sex organ **carpogonium**.

Following fertilisation the zygote may produce carpospores e.g. *Porphyra* by division directly or indirectly from zygote as in *Batrachospermum* and *Polysiphonia*.

Alternation of generations. Alternation of haploid and diploid multicellular generations occur. **Alternation of generations can be defined as following of two generations, gametophytic and sporophytic in regular sequence one after another.**

Parasite. Some red algae like *Harveyella* is found heterotrophically (as parasite) on other autotrophic, photosynthesizing red algae.

Economic importance. Red algae like *Gelidium* and *Gracillaria* is the source of **agar** jelly used in culturing micro-organisms.

Some rhodophytes as *Porphyra*, *Chondrus* are used as vegetables.

Carragenin from a red alga is used in the preparation of chocolate milk to keep chocolate from setting out. *Porphyra* is used as an important ingredient in soups and also cooked as flavouring agent with meat. *Chondrus* (Irish moss) is used in the preparation of various pharmaceuticals including laxatives and cosmetics. *Rhodymenia palmata* (dulse) is used as food and for preparation of medicines. Dulse was used as food at the time of famine in Ireland.

BROWN ALGAE (PHAEOPHYCEAE)

1. The brown algae include 2000 species of multicellular forms ranging in size up to giant kelps of 60-70 metres in length.
2. No unicellular phaeophyte is reported as in green and red algae.
3. They are prominent brownish green sea weeds that usually cover the rocks in the tidal zone and extend out in water 15 metres deep.
4. Identifying pigments of brown algae are chlorophyll *a* and *c* and the brown **fucoxanthin**. The fucoxanthin masks all other pigments.
5. *Laminaria* is attached with rocks in sea firmly by its holdfast. The lamina is photosynthetic and stipe is equal to stem of higher land plants.
6. *Sargassum* (floating form) is abundant in warmer seas. *S. natans* occurs in huge floating masses in North Atlantic and covers thousands of hectares. The area in which it is found is called **Sargasso** seas. Being found in such a huge quantity, it may be dangerous to ships in that area due to entangling of *Sargassum* at the bottom of ships.
7. On the cellulose cell wall, there is a covering of **phycocolloids** (alginic acid). Phycocolloids are responsible for :

   (a) protecting the brown algae from drying or freezing on their exposure to air.

   (b) preventing the brown algae by waves which mechanically beat them with rocks.
8. Alginic acid is a constituent of phycocolloid in cell walls of brown algae.
9. **Asexual reproduction** is quite common in brown algae and is affected by fragmentation of the thallus. The fragments may remain attached to substratum or float away and develop new plants as in *Sargassum*.
10. In many brown algae one celled globular structures **unilocular sporangia** (Fig. 6) are formed which produce **biflagellate** zoospores after meiosis.
11. In addition to unilocular sporangia, certain multilocular ellipsoidal structures are also found in brown algae as *Ectocarpus* called **pleurilocular sporangia**. They also produce zoospores but without meiosis they produce diploid plants (Fig. 7).

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12. Instead of zoospores non-motile **tetraspores** are produced in unilocular tetrasporangia in brown alga like *Dictyota*. The haploid tetraspores produced after meiosis give rise to male and female plants.

13. Morphologically the zoospores of brown algae are peculiar. Each bears two laterally oriented flagella. One of these is of **whiplash** type and another **tinsel**. They are of unequal lengths. In some species one of the two flagella may be rudimentary.

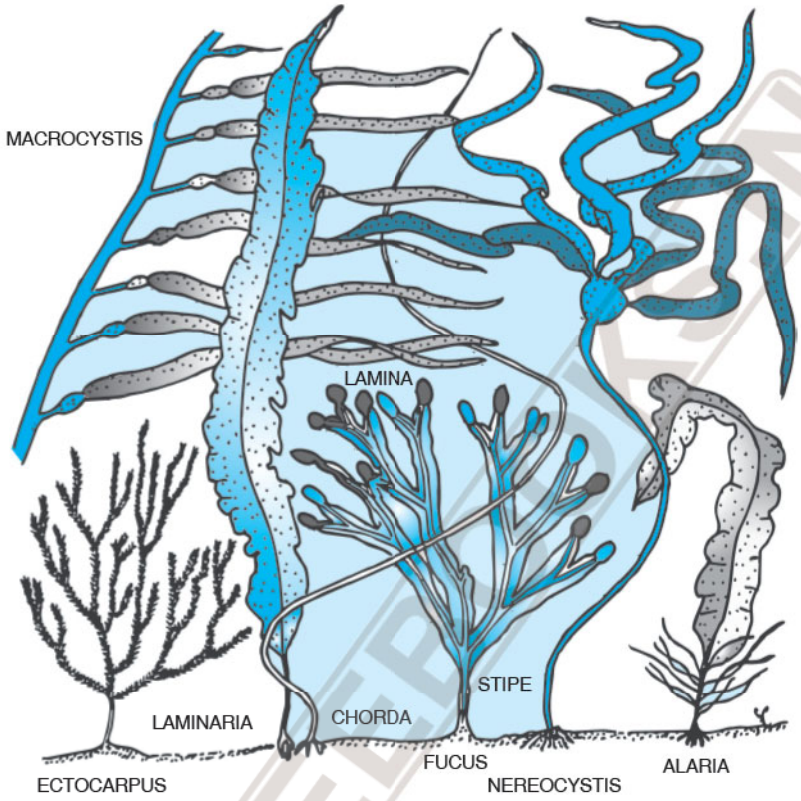

Fig. 5. Some kinds of brown algae or kelps, all of which are multicellular marine plants.

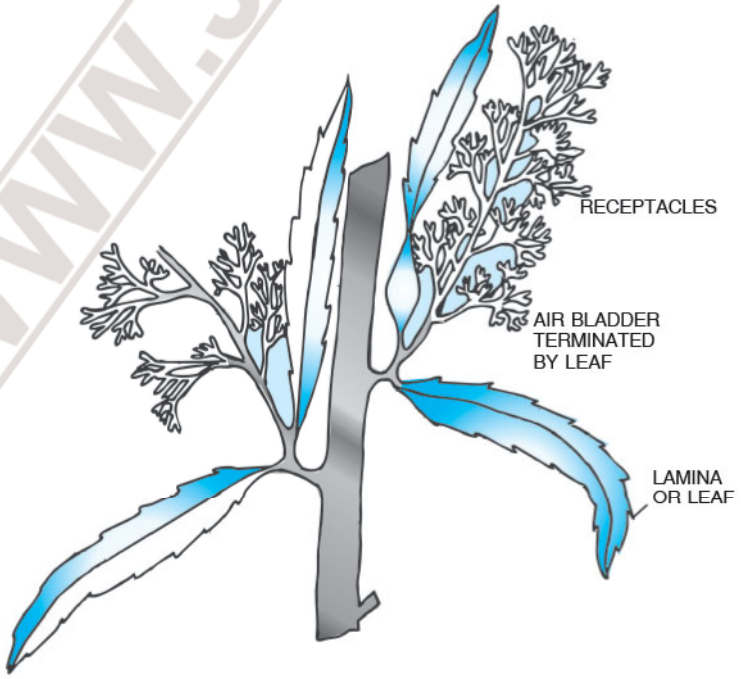

Fig. 6. Part of *Sargassum* (a brown alga).

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14. In brown algae, **sexual reproduction** is variable. It may be by fusion of flagellated motile, similar gametes (**isogamous**) or due to fusion of small motile, flagellated sperm and large stationary egg (**oogamous**). *Ectocarpus* consists of two kinds of plants that are similar in size and structure. However, one produces gametes and the other produces spores. The diploid form produces haploid spores (called **zoospores**) or haploid plants. These produce haploid gametes to produce a diploid zygote. This develops into a plant completing the life cycle. In some other brown algae, diploid sporophyte generation can be distinguished from haploid gametophytic generation. In some as in *Fucus*, diploid phase is dominant and gametophyte generation is highly reduced. This type of condition is found only in higher angiospermic vascular plants.
15. **Algin** (Alginic acid) produced commercially from kelps as *Laminaria* (a pectin-like component of cell wall) is a colloidal carbohydrate. This can gel and thicken mixture and is widely used in making ice-cream, with it the ice-cream manufacturer can use much less real cream and still have a smooth creamy product. Algin is also used for the preparation of candy, tooth paste and cream cosmetics. Many species of *Laminaria* and *Sargassum* are used as **food.**

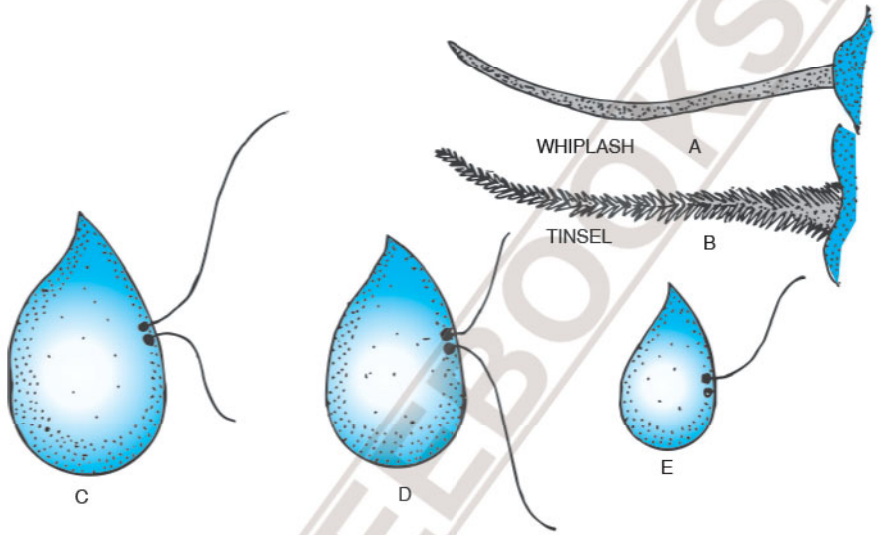

Fig. 7. Types of flagella in Phaeophyta.

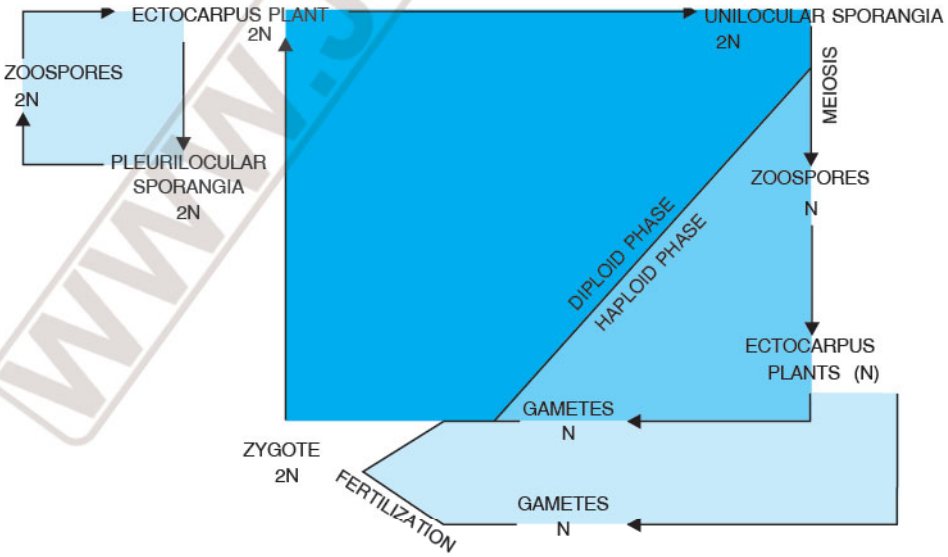

Fig. 8. Graphical life cycle of *Ectocarpus* showing diploid and haploid isomorphic plants.

GREEN ALGAE (CHLOROPHYCEAE)

1. More than 7,000 species of green algae live in a wide variety of **habitats** from salt to freshwater. Most of the chlorophyta live in **freshwater**, either as part of the plankton or attached to submerged rocks and twigs and some are **marine**. While others grow on the surface of **moist soil**. Still others are found as epiphytes. Several others are designated as snow

or ice algae, because of their habitats. Some green algae are components of **lichens** as phycobiont partner. Some species have lost their chlorophyll and have become **parasites** upon other plants e.g. *Cephaleuros* causes rather serious disease of tea and pepper plants. A few green algae *Zoochlorella* are associated with animals (**epizoic**) as shells of molluscs, sponges etc. One of the most interesting epizoic cases is of green alga which grows upon the hair of the **three toed sloth**, giving the hair of this tropical animal a greenish colour. Thus the fur of sloth (a tree dwelling mammal) turns green.

2. Green algae exhibit an extraordinary **variety in form and shape** of their thallus as :
   - **(a)** Unicellular motile forms e.g. *Chlamydomonas* can be placed in Protista also.
   - **(b)** Unicellular non-motile forms e.g. *Chlorella*
   - **(c)** Colonial motile forms e.g. *Volvox*, *Pandorina* (Fig. 1)
   - **(d)** Colonial coccoid forms e.g. *Hydrodictyon*
   - **(e)** Colonial palmellate forms e.g. *Tetraspora*
   - **(f)** Filamentous forms :
     - **(i)** Unbranched : *Ulothrix*, *Spirogyra* (Fig. 1)
     - **(ii)** Branched : *Cladophora* (Fig. 1)
   - **(g)** Heterotrichous : *Coleochaete*
   - **(h)** Foliaceous and parenchymatous: *Ulva* can be placed in brown algae also.
   - **(i)** Umbrella-like : *Acetabularia*
   - **(j)** Siphonaceous : *Vaucheria* (Fig. 1)
3. The chloroplast is the pigment containing organelle in green algae and contains four pigments as chlorophyll *a* and chlorophyll *b* (green). The yellow pigments are carotene and xanthophyll (carotenoids). The colour of green algae is due to excess of chlorophyll. Pigments lie in the grana of chloroplast as in higher plants.
4. Cell wall is secreted by protoplast and consists of two layers. Inner layer is mainly made up of **cellulose** which occurs in the form of microfibrils. Outer layer is made up of **pectone.** The fibrils in cellulose are fine thread-like structures. The fibrils are in a network at right angles to each other.
5. Protoplast is bounded by a plasma membrane and in many genera a large central vacuole is present (*Spirogyra*). Mitochondria, endoplasmic reticulum, Golgi body etc. are present in green algal cells.
6. Many green algae bear **pyrenoids**. Each pyrenoid is made up of central protein body surrounded by starch covering. They are considered as masses of starch and protein reserve.
7. Green algae bear well defined nucleus, thus eukaryotic in nature.
8. They reproduce by asexual and sexual methods. Asexual reproduction occurs commonly by **zoospore** formation. In addition asexual spores like **aplanospores, hypnospores** and **akinetes** are also common.
9. Sexual reproduction takes place by gametes formation. The gametes are usually similar to zoospores in morphology and mode of formation. Gametes may be naked or covered by a wall.
10. Sexual reproduction may be of **isogamous, anisogamous** or **oogamous** type.
11. After syngamy, diploid zygote is produced. It develops a thick wall to form zygospore. Meiosis occurs and finally plants are produced either directly (*Spirogyra*) or by meiozoospore formation (*Ulothrix*) etc.

Methods of asexual reproduction

(i) Zoospores. They have been noticed in the aquatic members. Zoospores are motile and develop into new plants (*e.g. Chlamydomonas, Ulothrix*). Zoospores may be simple and with two flagella *e.g, Chlamydomonas, Cladophora* etc. or may be compound (*Vaucheria*- **Synzoospores**)or may have an **apical ring** of cilia (*Oedogonium*). **Quadriflagellate** zoospores are found in *Ulothrix* and *Cladophora*.

(ii) Aplanospores. These **non-motile** spores are reported in **terrestrial** members. These are thin-walled, formed by the cleavage of protoplast within a cell. These are produced in **aplanosporangium** e.g *Ulothrix*.

(iii) Hypnospores. These are **thick walled non-motile spores** produced under unfavourable conditions. These are rich in food material and on the onset of favourable conditions, these germinate to give rise to new plants e.g. *Vaucheria*.

(iv) Akinetes. It is a method for perennation rather than multiplication. The characteristic feature of akinete is that the **entire cell gives rise to a new plant**. During its formation, the protoplast of the cell rounds off, contracts and loses water. The cell gets filled with starch and oil. On the approach of favourable conditions, these grow into new individual e.g. *Nostoc*, *Cladophora*.

(v) Tetraspores. In brown algae certain cells form **tetrasporangia** which produce non-motile spores known as **tetraspores**.

These are formed due to meiosis, so these germinate to develop into haploid plants though produced on the diploid plant.

Such spores are produced by red algae also e.g. *Polysiphonia*.

(vi) Palmella stage. Sometimes, the zoospores do not come out of the parent cell and get enclosed in a mucilaginous envelope. These divide and redivide to form more daughter cells resulting in a small colony. This stage is known as **Palmella stage**. It is a temporary stage and under favourable conditions. e.g *Chlamydomonas, Ulothrix*.

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Table 6. Differences between Zoospores and Aplanospores.

Characters	Zoospores	Aplanospores
1. Motility	They are motile.	They are non-motile.
2. Cell wall	They do not have a definite cell wall around	They are surrounded by a thin cell wall around them.
3. Shape	It is ovoid, or pear shaped.	It is spherical in shape.
4. Number	Produced 2-32 in a cell.	They are produced from 1-16 in a cell.
5. Conditions	Produced under favourable conditions of life.	Produced under unfavourable conditions of life.
6. Structure	Bear flagellae, have stigmata, contractile vacuoles and prominent choroplast.	They do not bear flagella, do not have stigmata, contractile vacuoles.
7. Liberation	Always liberated in water and germinate outside the zoosporangium.	Not liberated, but germinate *in situ*.

Table 7. Differences between Akinete and Aplanospore.

Characters	Akinete	Aplanospores
1. Division	Produced without division of protoplast.	Produced with or without division of protoplast.
2. Wall	The cell wall and spore wall are not separate and distinct.	The wall of aplanosporangium and the wall of spores are distinct.
3. Storage	Store lot of reserve food.	Store less reserve food.
4. Perennation	Perennates much longer.	Perennates for a shorter interval.

Table 8. Comparison between Aplanospore and Hypnospore.

Characters	Aplanospore	Hypnospore
1. Cell wall	Cell wall is relatively thin.	Cell wall is relatively much thicker.
2. Perennation	Perennate for a short period only.	Perennate for a much longer period.
3. Number	Produced very commonly	Produced less commonly.

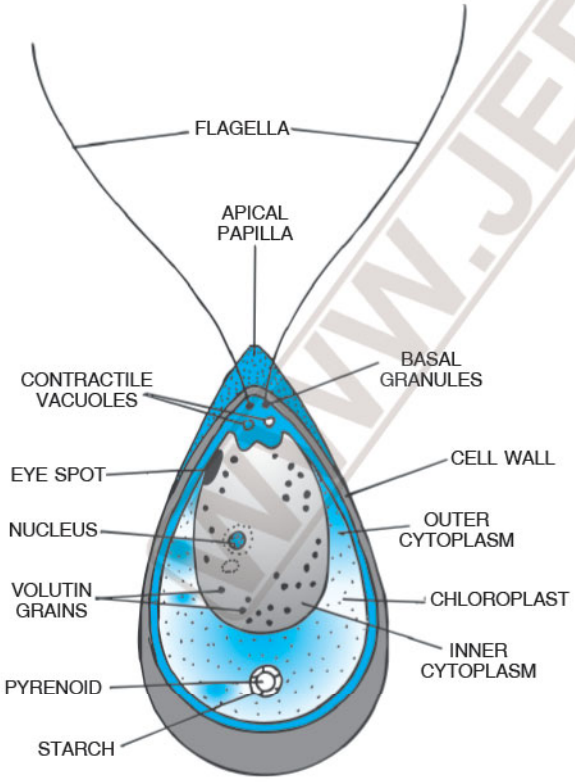

Fig. 9. *Chlamydomonas.*

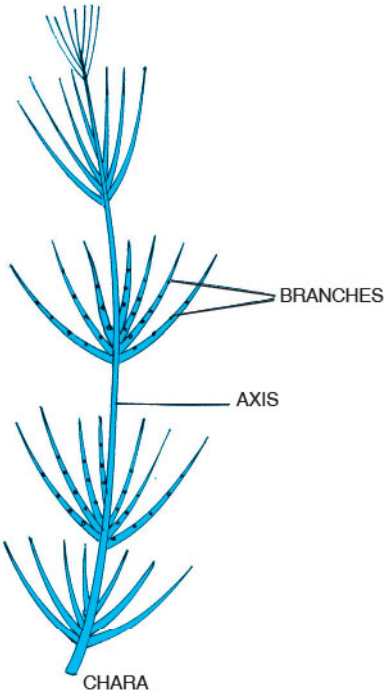

Fig. 10. *Chara,* a green alga.

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Table 9. Comparison of Red, Brown and Green algae.

Characters	Red algae	Brown algae	Green algae
1. Occurrence	Marine	Marine	Fresh water
2. Organisation	Few unicellular forms	Unicellular forms absent	Several unicellular forms present
3. Chloroplast	Thylakoids or lamellae are not stacked	Thylakoids stacked in groups of three	Thylakoids stacked in groups of 2-20
4. Chlorophyll	Chl. *a* and Chl. *d* present	Chl. *a* and Chl. *c* present	Chl. *a* and Chl. *b* present.
5. Fucoxanthin	Present	Present	Absent
6. Phycobilins	Present	Absent	Absent
7. Reserve food	Floridean starch	Laminarian	Starch
8. Movement	Non-motile	Present	Present

ECONOMIC IMPORTANCE OF ALGAE

Positive Importance

1. Algae as food. Algae constitute an important source of food for the fishes and other aquatic animals, mammals and other animals including man directly or indirectly. Miller (1972) suggested the role of algae in the production of protein rich human food. People in some coastal countries like China and Japan have used algae as a source of food. Some of the commonly used algae for food are, *Chlorella*, *Porphyra*, *Ulva*, *Chondrus*, *Laminaria*, *Alaria*, *Nostoc*, *Codium*, *Rhodymenia* and *Monostroma.*

2. Algae as fodder. Many sea weeds such as *Ascophyllum*, *Fucus*, *Laminaria*, *Sargassum* and *Rhodymenia* are used as fodder for sheep, goats, cattle and poultry in many countries like France, USA, Norway, China, Denmark, New Zealand and Great Britain. The chopped kelps are given to sheep and chickens.

Planktonic algae form the major food for many fresh water and marine animals like protozoans, crustaceans and fishes. Fishes, in turn, form an important source of proteins for humans, thus providing algae as an indirect food through food chains.

3. Algae in industry. Many products of commercial importance are obtained from algae. Some of them are as follows :

(i) Agar agar. It is a jelly like non-nitrogenous product, extracted in water from a number of red algae like *Gelidium*, *Gracilaria*, *Chondrus* and other genera. It is a complex polysaccharide consisting of agarose and agaropectin which is produced and stored in cell walls along with cellulose. It is soluble in hot water, solidifies at room temperature and melts above 90° C.

Agar is used as a stabilizer or emulsifier in food stuffs, cosmetics, leather, medicines and paper industry. It is used in textiles, baking, meat industry, preservation and canning of fish. Medicinally it is used as a laxative. Most important use of agar is in the preparation of culture media in pathological and tissue culture laboratories.

(ii) Carrageenin. It is similar to agar agar occurring as a complex polysaccharide esterified with sulphate. It is obtained from the cell walls of *Chondrus crispus* and *Gigartina.* It is widely used as stabilizer of emulsions in paints and cosmetics. It is also used in textiles, leather, breweries, food and pharmaceutical industry.

(iii) Alginates. Salts of alginic acid are called alginates. These are extracted from the cell walls of many brown algae like *Laminaria*, *Macrocystis*, *Ascophyllum*, *Fucus*, *Lessonia*, and *Sargassum* etc. It is a polysaccharide made up of galuronic acid and manuronic acid. Alginates are used as stabilizers, emulsifiers, gelling agents and filters. They are used as thickening agents in the preparation of soup, sauce, jellys, creams, printing ink etc. It is used in the preparation of dental impression powder, ointments, dressing materials and to stop bleeding.

(iv) Diatomite. The fossilized diatoms deposited in the sedimentary rocks from diatomaceous earth known as diatomite. Big deposits of Diatomite are found at Lompoc in California. It is white, soft and porous material which is insoluble and chemically inert and heat resistant. It is used as filter, absorbent and insulator in oil and chemical industries, furnaces, refrigerators, sound proof rooms, tooth powder etc.

(v) Mucilage. Extracted from *Careragaen* and *Chondrus* etc., mucilage is used as stiffening agent in cosmetics, shaving creams, shoepolish, shampoos etc.

(vi) Minerals and Elements. Brown seaweeds like kelps are rich in some minerals. Soda and iodine are extracted from *Laminaria*, *Fucus*, *Macrocystis* etc. Bromine is obtained from *Rhodomella* and *Polysiphonia.* Other important minerals such as copper, cobalt, iron, zinc, manganese, vanadium, potash, boron and chromium are also obtained from many seaweeds.

4. Algae in agriculture

(i) Nitrogen fixation. Many blue green algae are known to fix atmospheric nitrogen and enrich the nitrogen content of soil particularly of rice fields. The most common nitrogen fixing blue green algae are—*Nostoc*, *Anabaena*, *Aulosira*, *Tolypothrix*, *Scytonema*, *Calothrix*, *Stigonema*, *Oscillatoria* and many others.

(ii) Soil reclamation. The barren and alkaline soils can be reclaimed by inducing the growth of blue green algae. They cause decrease in pH and increase in nitrogen, phosphorus, organic matter and water holding capacity of the soil.

(iii) Soil formation and conservation. Some algae grow symbiotically in the thalli of lichens. The lichens are the pioneers of plant succession on barren rocks forming primary soil. Some algae like *Anabaena*,

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Tolypothrix and *Lyngbya* help in soil conservation by preventing soil erosion.

(iv) Fertilizers and manures. Seaweeds are widely utilized as manures near coastal regions. They are rich in potassium, phosphorus, microelements and some growth substances. The blue green algae are richer in nitrogen and phosphorus. Thus, a mixture of seaweeds and blue green algae may serve as a good fertilizer source. In India, *Turbinaria*, *Anabaenopsis* and *Spirulina* are used as fertilizers and green manure.

5. Algae in sewage disposal. Direct sewage disposal causes water pollution. Sewage consists of organic and inorganic materials. It is poor in oxygen and can be aerobically decomposed by the growth of many unicellular algae like *Euglena*, *Chlorella*, *Scenedesmus* etc. The sewage is rich in sulphur, phosphorus, nitrogen, potassium and other mineral nutrients. The photosynthetic activity of the algae produce oxygen which in turn is utilized by bacteria for sewage decomposition. The reclaimed sewage water can be irrigated to crops and can serve as fertilizer.

6. Algae in medicine

(i) Some algae yield antibacterial substances effective against a number of gram-positive and gram negative bacteria. **Chlorellin** is the first antibiotic obtained from *Chlorella* in 1944. Some other algae like *Ascophyllum*, *Halidrys*, *Laminaria*, *Cladophora*, *Lyngbya*, *Polysiphonia* and *Rhodomela* yield antibiotic like substances.

(ii) Many seaweeds which have high content of iodine are utilized in the preparation of various goitre medicines.

(iii) The members belonging to Charales have the property to kill larvae and thus may be helpful in checking the mosquitoes.

(iv) Agar agar is used in pills and ointments and as a laxative in a number of medicines.

(v) Carrageenin serve as a blood coagulant.

(vi) Many algae like *Corallina* and *Codium* are utilized in the preparation of extracts which are used in the treatment of kidney, bladder and lung diseases.

7. Algae in space research. Recently, unicellular green algae *Chlorella* and *Scenedesmus* have been found to be useful in space research programmes. Carbon dioxide and other body wastes like urine and faeces of the astronauts are decomposed by these algae to produce oxygen and food during space flight trips. The biologists are trying to devise the biological system which would provide a complete recycling of such materials.

8. Algae in natural fuel resources. The petroleum and natural gas resources which are organic in origin are also contributed by marine algae. The planktons fed upon by marine animals and the dead remains of marine animals and plants, in turn, accumulated at sea bottom got buried in sedimentary rocks. These were decomposed anaerobically and became converted into oil and gas.

Negative importance

1. Toxicity. Many algae produce toxins which can cause the death of aquatic animals. Toxins produced by *Prymnesium parvum*, *Gymnodinium veneficum*, *Microcystis*, *Gonyaulax* can lead to the death of fishes and other aquatic animals. Some toxic planktonic algae may be consumed by human beings along with drinking water and may cause various diseases. *Anabaena* and *Microcystis* cause gastric troubles, *Gymnodinium brevis* produce respiratory disorders and *Lyngbya* and *Chlorella* can cause skin infections.

2. Parasitism. *Cephaleuros*, a green algae, is parasitic in nature and cause red rust of tea. *Polysiphonia fastigata* is parasitic on a brown alga-*Ascophyllum nodosum*.

3. Damage. Some seaweeds grow on metallic and wood-work of ships and boats causing fouling, corroding and destruction. Some algae grow on the walls of historical buildings and monuments and spoil them. Some algae cause destruction to textiles and some reduce the quality of water through contamination.

DID YOU KNOW?

- **Space alga:** *Chlorella pyrenoidosa*
- **Umbrella alga:** *Acetabularia*
- **Rolling alga:** *Volvox*
- **Largest alga:** *Macrocystis pyrifera* (about 60 m. length)
- **Brown algae:** Also called as Kelps
- **Red snow:** *Chlamydomonas nivalis*
- **Green yellow snow:** *Chlamydomonas yellow stonensis*
- **Morris:** Father of algae.
- **M.O.P. Iyenger:** Father of Indian Phycology

4. Other effects. Algal growth in water reservoirs like ponds, pools and lakes causes the loss of aesthetic and fishing values. *Oscillatoria*, *Spirogyra* and diatoms clog the water filters and change the taste and colour of water, and produce foul odour. *Anacystis* and *Chaetophora* corrode the concrete and metallic walls of pipes and boilers by secreting carbonic acid, oxalic acid and silicic acid. Some excrete toxins in water to make it unfit for drinking. Algae contamination cause changes in pH, CO_2, biocarbonate and oxygen content of water.

BRYOPHYTES

Habitat

1. The members of bryophytes live in more or less shady, moist, cold places in groups. Some bryophytes inhabit bogs and swamps. Still others in rain forests occur abundantly as epiphytes, on leaves and trunks of trees. They are very commonly noticed on damp soils, rocks, walls etc. None is marine.

Structure

2. The plants represent two morphologically distinct generations *i.e.* gametophytic and sporophytic.

3. Gametophytic phase is the dominant phase of the cycle and in general plant body term is used for this phase.

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4. The plant body in primitive forms like *Riccia* and *Marchantia* is thalloid (Fig. 11 A, C) but in mosses like *Funaria*, it may be differentiated into rhizoids, stem and leaves.

5. The thalli *Riccia* and *Marchantia* are attached to the substratum by unicellular, unbranched rhizoids, but in mosses like *Funaria*, rhizoids are branched, multicellular and obliquely septate.

6. The plant body is made up of simple thin walled parenchymatous cells. Xylem, phloem (vascular tissue) and mechanical tissue (sclerenchyma etc.) are altogether lacking in bryophytes.

7. Bryophytes are found in moist places due to the following reasons :

(a) In the absence of true roots, cells are able to absorb water directly from the ground or atmosphere.

(b) Biflagellate sperms of bryophytes need water for their movement to reach archegonium (female sex organ) for fertilization.

8. Mosses seldom reach heights. *Funaria* is 1-3 cm in height. They rarely grow more than 15 cm in height. Tallest species of moss has been reported from New Zealand having the size of 60 cm.

Economic importance

9. The peat deposits of *Sphagnum* (an aquatic moss) are cut into blocks, dried and used as fuel, because of its superior **absorptive powers** and **antiseptic** properties, *Sphagnum* is used for dressing the wounds. *Sphagnum* due to its ability to retain water is used for packing plants and cut flowers which are transported to far away places. Gardeners also use this moss for **vegetative propagation** at the time of air layering etc. **Peat** is valuable for farmers. When it is added to clayey soils, it improves the texture of the soil. **Peattar, ammonia** and **paraffin** are some of the by products of peat. It is great **soil builder**, it fills the ponds, pools etc. and finally due to its excessive growth, they are completely filled. The debris gradually is converted into solid earth. *Sphagnum* in the pools etc. look like soil and hence known as **quacking bogs.**

10. Bryophytes are important in soil **erosion**. The extensive carpets or mats, which they form hold the soil in place and hence prevents its washing away.

Reproduction

11. At maturity, the gametophytes are nutritionally independent, while sporophytes are dependent upon as well as being permanently attached to gametophytes.

12. Bryophytes reproduce vegetatively by tubers, gemmae, fragmentation etc.

13. Male sex organ is called **antheridium**.

14. Antheridium is made up of mass of androcytes enclosed by sterile jacket.

15. Each androcyte gives rise to bi-flagellate sperms (male gamete).

16. Sexual reproduction is of **oogamous** type.

17. Female sex organ is called **archegonium.**

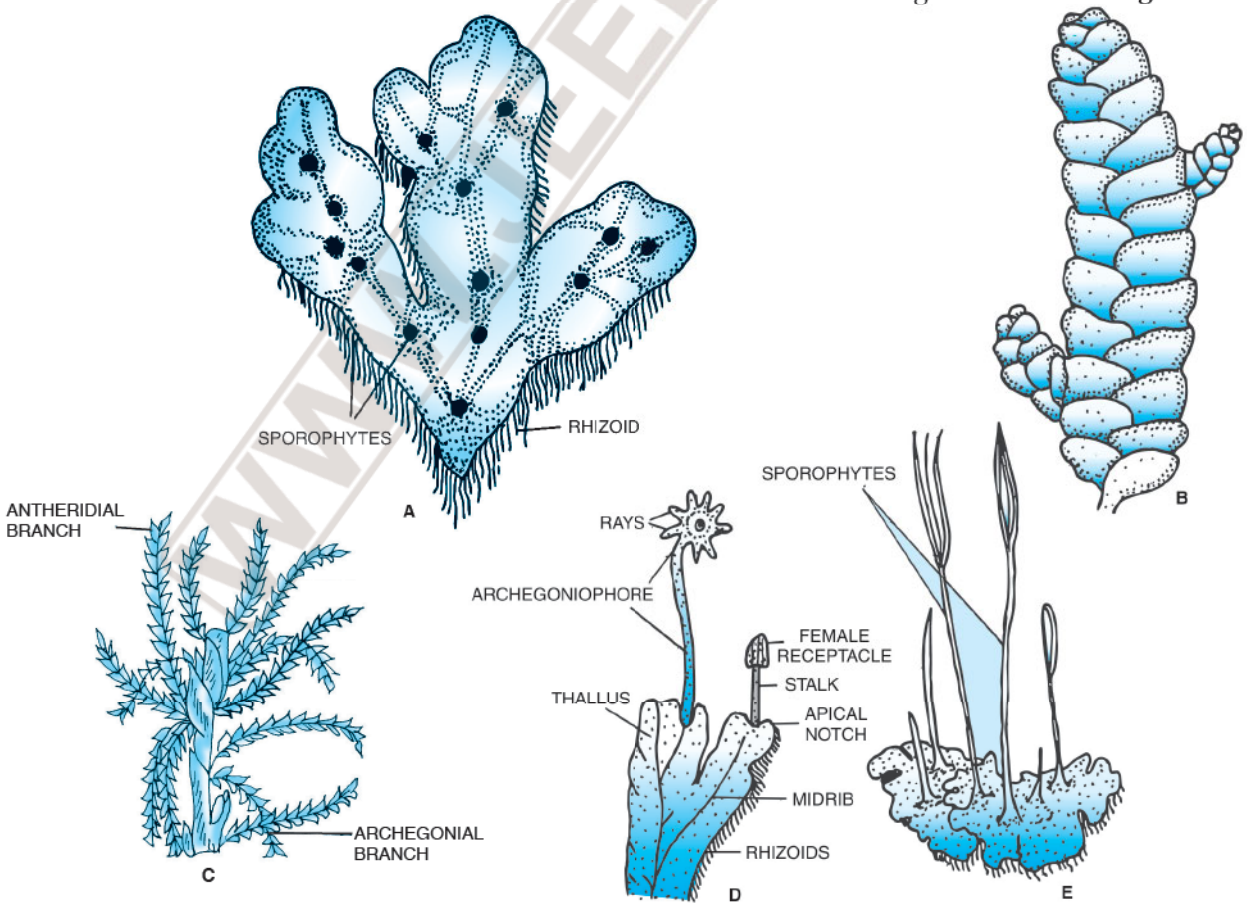

Fig. 11. Bryophytes. **A.** *Marchantia*, **B.** *Porella*, **C.** *Sphagnum*; **D.** *Marchantia* (showing stalked sex organs), **E.** *Anthoceros.*

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18. Each archegonium is a multicellular flask-shaped structure. Its lower dilated, swollen part is called **venter** and slender, elongated upper part is called **neck**.

19. Sex organs antheridium and archegonium are multicellular and jacketed.

20. Venter encloses egg (female gamete) and venter canal cell. Neck encloses a row of neck canal cells.

21. The syngamy (fertilization) takes place in water. The sperms swim in water to reach near the archegonium. One of the sperms fuses with egg to form diploid zygote.

Sporophyte

22. The zygote undergoes continuous divisions without undergoing any resting period.

23. The developing embryo is retained inside the venter, where it finally develops into **sporogonium**.

24. The sporophytes (sporogonia) are partially or completely dependent upon gametophyte.

25. The sporogonium is usually differentiated into foot, seta and capsule.

26. In *Riccia* foot and seta are absent. Capsule is embedded in the thallus. In *Riccia* even the sex organs are found inside the thallus.

27. In capsule meiosis occurs in spore mother cells to form haploid spores.

28. The spores are homosporous *i.e.* only of one type—the young gametophyte.

29. Haploid spores, after dispersal from capsule may germinate either directly into gametophytic thallus (*Riccia*, *Marchantia*) or may form filamentous **protonema** which bears adventitious buds to give rise to leafy plant (gametophore).

Table 10. Differences between Thallophytes (algae) and Bryophytes.

Thallophytes (Algae)	Bryophytes
1. Thallophytes are mainly aquatic.	Bryophytes are terrestrial found on shady and moist places.
2. Plant body is unicellular or multicellular filamentous. In some layers of parenchyma are found.	Plant body is multicellular thalloid made up of sheets of parenchymatous cells except protonema stage in mosses.
3. There is no or ill defined tissue differentiation.	There is well defined tissue differentiation.
4. The rhizoids are either absent or most simple in the form of hapteron or haustorial cell.	Unicelled or multicellular rhizoids are always present.
5. Air pores and stomata are absent.	Air pores, stomata both may be present.
6. Asexual reproduction takes place by mitospores like zoospores, aplanospores, chlamydospores, hypnospores, akinetes etc.	Complete absence of mitospores. Asexual reproduction takes place by vegetative methods only.
7. Every cell is capable of growth and development.	Only the specialised cells are capable of growth and development.
8. Sexual reproduction ranges from isogamy, anisogamy to oogamy.	Sexual reproduction is only of oogamous type.
9. The sex organs are unicellular or multicellular but never surrounded by sterile jacket.	The sex organs are always multicellular and jacketed.
10. The female sex organ is called as oogonium.	The female sex organ is called as archegonium.
11. The zygote is liberated and usually passes into a resting state.	The zygote is neither liberated nor passes into the resting stage.
12. No embryo is formed.	Embryo is formed.
13. Gametophytic and sporophytic stages are independent.	Sporophyte is always dependent upon gametophyte.
14. They show ill defined type of homologous alternation of generations.	They show well defined heteromorphic type of alternation of generations.

Table 11. Differences between Sporophyte and Gametophyte.

Characters	Sporophyte	Gametophyte
Definition	Multicellular, diploid structure in the life cycle of a plant.	Multicellular, haploid structure in the life cycle of a plant.
Ploidy	Diploid.	Haploid
Formation	From zygote.	Due to germination of a meiospore.
Production	Produces spores after meiosis.	Produces gametes without meiosis.
Reproduction	Takes part in asexual reproduction. Meiospores do not take part in sexual reproduction, however they form gametophyte.	Takes part in sexual reproduction. Gametes fuse to form diploid zygote.

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Table 12. Differences between Antheridium and Archegonium.

Character	Antheridium	Archegonium
1. Sex organ	Male	Female
2. Shape	Rounded or club shaped in outline.	Flask shaped in outline.
3. Structure	Made up of jacket and mass of androcytes.	Made up of neck and venter.
4. Number of gametes	Produces large number of male gametes or spermatozoids.	Produces single female gamete i.e. egg or oosphere in venter.
5. Mobility of gametes	Male gametes are motile and flagellated.	Female gamete is non-motile and non-flagellated.

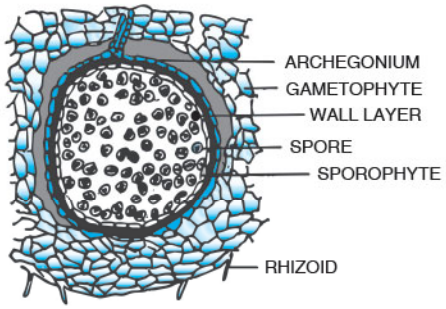

Fig. 12. V.S. *Riccia* thallus with embedded *Sporogonium*.

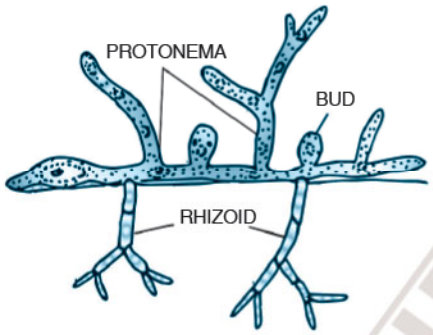

Fig. 13. Protonema of a moss.

Alternation of generations

30. Bryophytes exhibit a distinct and heteromorphic **alternation of generations** in which two phases gametophytic and sporophytic follow each other in regular sequence.

31. First phase is gametophyte which produces male and female gametes in male and female sex organs respectively (*i.e.* antheridium and archegonium).

32. The sporophyte phase starts immediately after fertilization of egg and sperm with the formation of diploid zygote.

33. Zygote forms a diploid multicellular **sporogonium** which is usually differentiated into foot, seta and capsule (moss).

34. Haploid spores are formed after meiosis. Thus spore is the first cell of gametophytic generation.

35. Spore germinates to give rise to plant body (haploid) directly or after protonema formation.

36. Because a gametophytic stage alternates with sporophytic stage, a clear alternation of generations is present which is of heteromorphic type (See graphical life cycle of a moss in Fig. 14).

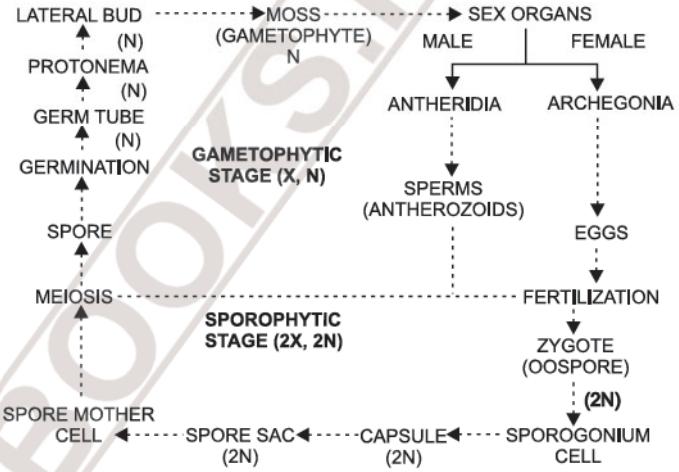

Fig. 14. Graphical life cycle of a moss.

37. Bryophytes are considered more advance than green algae as they represent multicellular sporophytic generation.

Depending on the characters of gametophyte. The bryophytes are divided into two groups :

(i) Liverworts **(ii)** Mosses.

(i) Liverworts. There are about known 10,000 species. Thallus is dorsiventrally flattened, attaches to the soil surface by many rhizoids produced from ventral surface of thallus. These rhizoids absorb water and minerals from the soil. The sex organs antheridia & archegonia may remain embedded in the thallus e.g. *Riccia* or they are produced on special structures raised above the thallus as in *Marchantia*. So the sporophyte remains embedded in the thallus or raised above the thallus. Sporophyte is differentiated into foot, seta and capsule. The spores germinate and directly give rise to thallus i.e. gametophyte e.g. *Riccia*, *Marchantia*, *Anthoceros*.

(ii) Mosses. Majority of mosses prefer damp, moist habitat but few are found in deserts, bogs and streams. '**Copper moss**' is found only in vicinity of copper thus acts as an indicator of copper deposits. **Liminous moss** is found in caves under the roots of trees and other dimly places and growth with golden green light. Thallus is erect and differentiated into root, stem and leaves. These

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parts are not true roots, stem and leaves but rhizoids are root like organs, central axis is stem like part and leafy appendages are leaflike organs of gametophore. The male and female sex organs are produced at the tip of branches in clusters on the same plant. This condition is monoecious. Antheridia are male gametangia produce male gametes, antherozooids which swim in water with the help of flagella.

Archegonia are female gametangia produce female gamete an egg. Many antherozooids are present but only one fertilizes the egg and forms a zygote. The zygote develops into a sporophyte. Sporophyte is differentiated into foot, seta and capsule. Foot remains embedded in the gametophytic tissue whereas seta (stalk like structure) and capsule (spore producing part of sporophyte) are raised above the gametophyte. Spores are haploid, they are dispersed in dry weather.

The spores germinate and develop protonema-an intermediate stage of gametophytic generation. The protonema bear vegetative buds which develop into leafy appendages. Thus from protonema gametophore is produced. Presence of protonema stage in the life cycle is characteristic of mosses. Protonema and gametophore together form the gametophytic phase in the life cycle. Thus distinct alternation of generations is seen in life cycle of mosses.

LIVERWORT *(MARCHANTIA)*

Morphology

1. Plant body is thalloid, green, dorsiventral and dichotomously branched.

2. On the dorsal side of the thallus, a median longitudinal groove is present.

3. Cup shaped bodies **gemma cups** are present on furrow of dorsal side.

4. On dorsal side, rhomboidal or polygonal areas are present.

5. Scales and rhizoids are borne on the ventral side of the thallus.

6. Rhizoids are colourless, unicellular structures. They are two types i.e. **smooth walled** and **tuberculate.** Tuberculate rhizoids bear peg like thickenings.

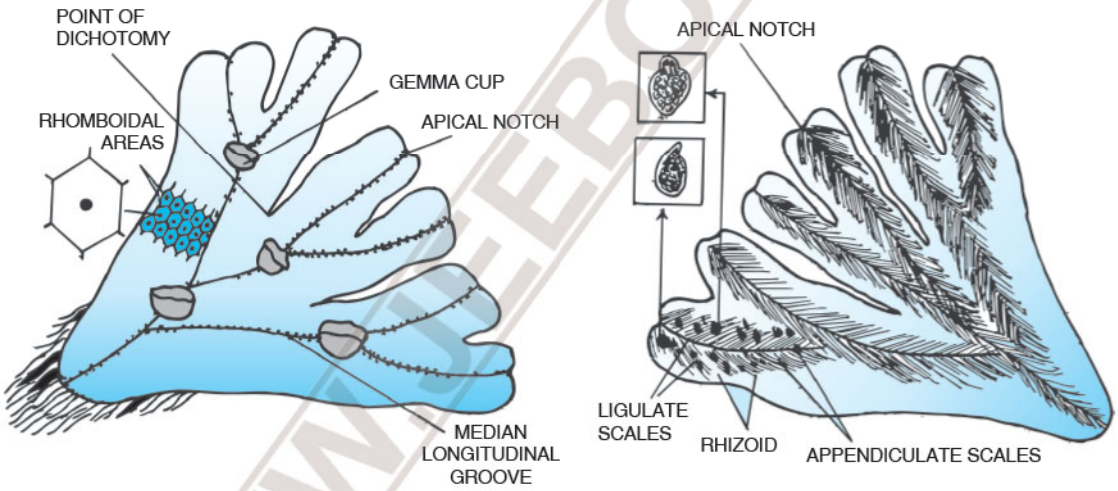

Fig. 15. *Marchantia* **A.** Dorsal view; **B.** Ventral view.

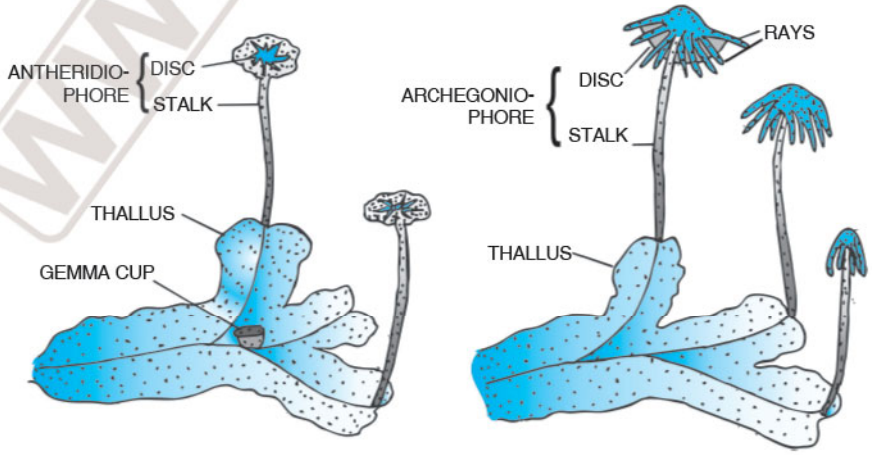

Fig. 16. *Marchantia* : **A.** Male thallus; **B.** Female thallus.

7. Scales are violet coloured, multicellular but one celled thick structures.

Male *Marchantia* (*Marchantia* with antheridiophore)

1. Each antheridiophore is differentiated into lower cylindrical long **stalk** and a terminal **disc.**

2. The disc is circular structure with 8-lobes and is called as antheridial disc.

3. Each lobe of the disc is provided with a row of embedded antheridia arranged in acropetal manner.

Female *Marchantia* (*Marchantia* with archegoniophore)

1. Dorsally, apices of thallus some upright branches appear to form archegoniophores.

2. Each archegoniophore is differentiated into lower cylindrical long stalk and a terminal disc.

3. The disc is 8-lobed structure.

4. The disc also bears 9 rays, which are hanging downwards like of umbrella.

5. On the ventral side of the lobes, archegonia hang in centrifugal fashion.

REMEMBER

- **Father of Bryology:** Hedwig
- **Father of Indian Bryology:** S. R. Kashyap
- **Gold mines of Liverworts:** Western Himalayas
- *Sphagnum* retains 18-26 times more water then its weight.
- Moss stage is the second stage in biological succession.

FUNARIA (MOSS)

Morphology (Fig. 17)

1. Adult gametophyte (gametophore) which appears from protonema is differentiated into (a) Rhizoids (b) Axis or stem and (c) Phylloid or leaves.

2. At the base of stem, branched, obliquely septate, multicellular colourless rhizoids are present.

3. Mature rhizoids turn brown.

4. Stem is erect and branches only once in extra-axillary fashion.

5. Stem is covered with small, simple, sessile leaves which are arranged in a spiral fashion.

6. Leaf is green, ovate in shape with acute apex. It has a distinct mid-rib. Margin is slightly serrated.

7. Main branch in young gametophore behaves as male shoot and side branch as female shoot.

Reproduction

1. Antheridia and archegonia are borne at the apices of branches.

2. Antheridia are surrounded by perigonial leaves and archegonia with perichaetial leaves.

3. The plants are autoecious and monoecious.

L.S. antheridiophore (Male shoot)

It shows the following important characters :

1. At the tip of male branch cluster of antheridia are present, intermingled with them are multicellular, green, filament-like structures are present, called as paraphysis. Their uppermost cell is swollen (Fig. 18).

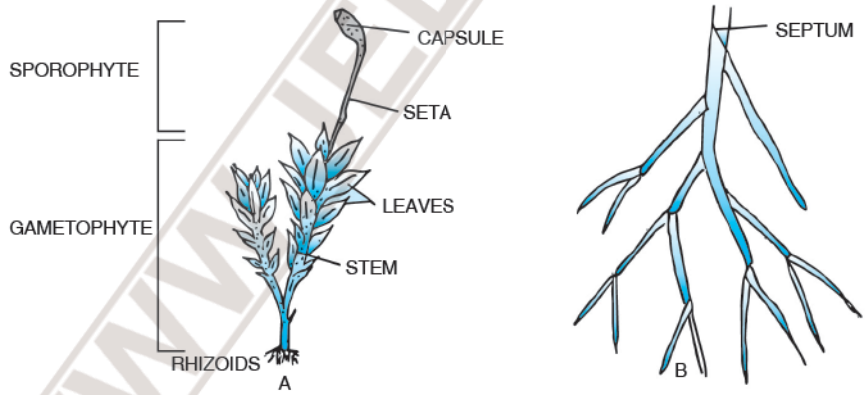

Fig. 17 *Funaria* : **A.** A plant with sporogonium; **B.** Rhizoid.

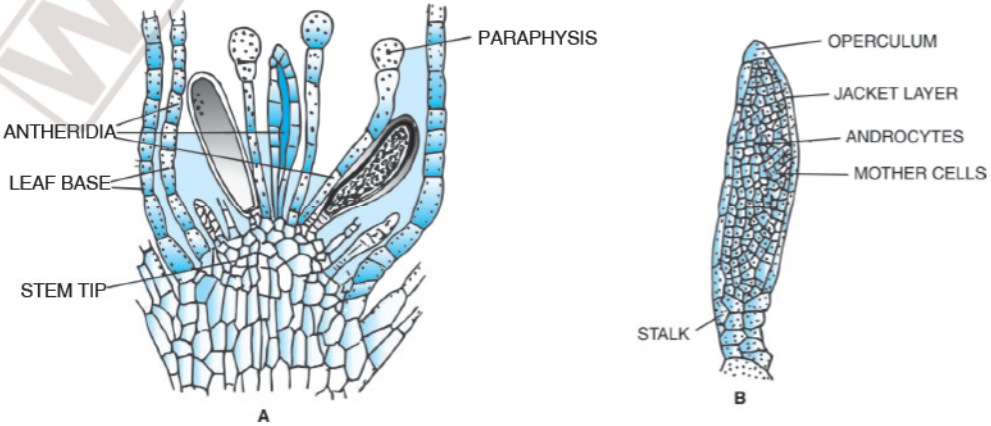

Fig. 18. A. V.S. Antheridiophore; **B.** V.S. Antheridium.

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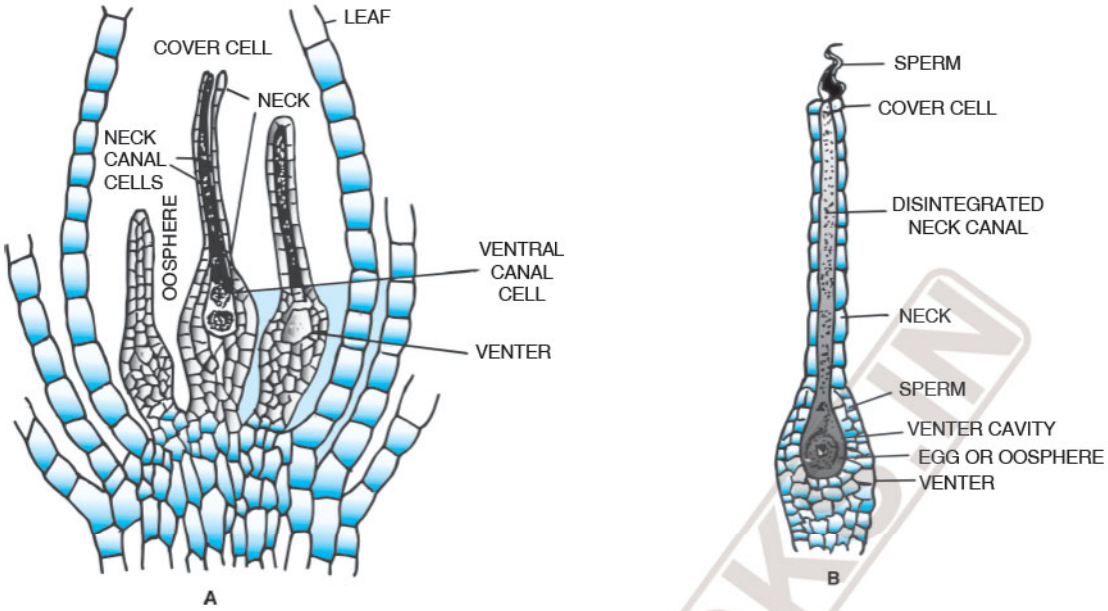

Fig. 19. A. V.S.Archegoniophore; **B.** Single archegonium V.S.

2. Each antheridium has a multicellular, massive stalk and club shaped body.

3. Jacket of body is made of single layer and contain numerous chloroplasts when young.

4. In the jacket cell, a cell present at the top 'Operculum' can be easily differentiated which is responsible for the liberation of sperms.

L.S. archegoniophore (Female shoot)

1. Several archegonia are borne at the tip of female shoot surrounded by perichaetial leaves (Fig. 19)

2. Green, filament like paraphysis are intermingled with them.

3. Uppermost cells of paraphysis are not swollen.

4. Each archegonium is present on a massive stalk.

5. The archegonium can be differentiated in long twisted neck and lower dilated one venter.

6. Neck is made up of six longitudinal rows of cells and venter is double layered.

7. Neck contains 6-10 neck canal cells. On the other hand venter encloses one egg and one venter canal cell.

L.S. sporogonium

1. The mature sporogonium can be recognised by three parts :

(a) Foot **(b)** Seta and **(c)** Capsule.

2. Foot is embedded in the tip of archegonial branch.

3. Seta is very long and slender. It bears sporogonium at its top.

4. Capsule is pear-shaped and is covered by ruptured calyptra.

5. Capsule can be further divided into 3 regions :

(a) apophysis **(b)** theca and **(c)** operculum.

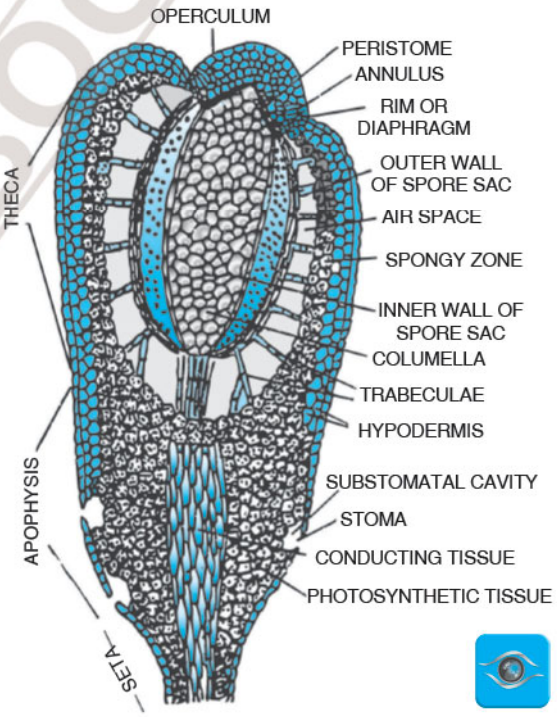

Fig. 20. L.S. Capsule of *Funaria.*

6. Apophysis shows the presence of assimilatory tissue and central conducting strand.

7. Theca has the epidermis which lacks stomata. Assimilatory tissue is represented by a few layers. Near spore sac region, it is ruptured to form air cavities with several trabeculae. Spore sacs are kidney shaped with outer wall made up of three layers and inner wall single layered. In the spore sac, haploid spores are present. In the centre, columella is present.

8. Operculum shows the presence of peristome, which are borne on transversely placed cells called diaphragm.

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9. Operculum is attached with theca by thin walled cells known as annulus.

10. Peristome is made up of two rows of triangular teeth. Each row contains 16 teeth.

11. Outer peristomial teeth are hygroscopic in nature and bears transverse bands.

12. Inner peristomial teeth are short, colourless and delicate.

Dispersal of spores. When capsule ripes, it begins to dry. As a result inner capsular tissues break up and spores are seen lying freely in the capsular cavity. Thin walled cells of annulus break and operculum falls away. Outer peristomial teeth with their typical hygroscopic movements lift the spores up in the air from the capsular cavity. Due to absorption of water, outer peristomial teeth become heavy and bend inwards. They straighten up in a dry weather.

Spore. Spores are haploid and spherical in shape. It is made up of two layered wall. Outer wall is thick and called **exine.** Inner **intine** is thin and made up of cellulose. The spore contains a haploid nucleus, proplastids and food material in the form of oil globules.

Germination of spore and formation of protonema. The spores germinate under favourable conditions. The spore wall absorbs water and exine ruptures due to swelling of spore. It gives rise to short tube like structure which divides to form filamentous, multicellular obliquely septate structure called **protonema.** Two types of branches can be distinguished in protonema :

(*i*) **Chloronemal branches** (Prostrate and upright).

(*ii*) **Colourless rhizoidal branches.** Lateral adventitious buds appear on protonemata which develop to form moss plant or gametophore.

Alternation of generations. Two distinct gametophytic and sporophytic generations are present in the life cycle of moss. *Funaria* plant is a gametophytic. It produces sperms and eggs, which fuse to form diploid zygotes. Zygote forms the sporogonium representing the sporophytic stage. In the theca region of capsule, the spore sac is present which contains diploid spore mother cell.

Table 13. Differences between Liverworts and Mosses.

Characters	Liverworts	Mosses
1. **Symmetry**	Dorsiventral	Radial
2. **Branching**	Dichotomous	Lateral but extra-axillary
3. **Plants**	Thalloid or foliose	Foliose
4. **Midrib**	Absent	Non-vascular midrib present in leaves.
5. **Rhizoids**	Unicellular and unbranched	Branched, multicellular and obliquely septate
6. **Scales**	Usually present	Absent
7. **Capsule**	Simple	Complex, differentiated into apophysis, thica and operculum
8. **Stomata on sporogonium**	Absent	Present on capsule wall
9. **Columella**	Absent	Present in capsule
10. **Dehiscence**	By elaters	By peristome
11. **Protonema**	Absent	Present

ADDITIONAL USEFUL INFORMATIONS ABOUT BRYOPHYTES FOR COMPETITIVE EXAMINATIONS

- ***Sphagnol*** *used is for skin disorders extracted from* ***Sphagnum.***
- *Elaters exhibit* ***xerochasy.***
- ***Riccia fluitans***, ***Riella*** *and* ***Ricciocarpus*** *are aquatic bryophytes.*
- ***Funaria*** *is also known as cord moss.*
- *A capsule of* ***Marchantia*** *forms about 3,000,000 spores.*
- ***Pogonatum*** *sporogonium is without apophysis.*
- *Calyptra is loose cap-like portion of capsule.*
- *Flat roof of columella is called* ***epiphragm.***
- *Central sterile column of capsule is called* ***columella.***
- *Bryophytes are non-vascular plants with multicellular sex organs.*
- *Mature* ***Riccia*** *sporogonial cells are always haploid.*
- *Erect gametophyte of bryophyte is called* ***gametophore.***
- *Sterile hairs mixed with sex organs are called* ***paraphyses.***

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PTERIDOPHYTA

The pteridophytes are flowerless, seedless, spore producing vascular plants which have successfully invaded the land.

The land plants have complex internal structure and pteridophytes represent an intermediate position between bryophytes and spermatophytes (gymnosperms and angiosperms). The pterido- phytes are called vascular cryptogams because among cryptogams, the vascular strands are present only in pteridophytes. Water is required for movement of sperms. Thus, gametophytes are water loving. The seed bearing plants have succeeded them and relegated pteridophytes to lower position in plant kingdom. Presently, pteridophytes are represented by a smaller proportion of plants.

General characters of pteridophytes

1. Habit and Habitat. The plants are small sized annual or perennials. Most of them are terrestrial plants and thrive well under damp and shady conditions. However, some grow in sandy soils in xeric climates (e.g. *Selaginella lepidophylla*). Some are aquatic also e.g. *Salvinia*, *Azolla* and *Marsilea*. Some are epiphytes also e.g. *Selaginella oregana*, *Ophiglossum pendulum* etc. There are two types of general categories in pteridophytes (a) **Megaphyllous** with large leaves e.g. ferns and (b) **Microphyllous** with small leaves e.g. *Equisetum* and *Selaginella*.

The compound leaves of *Adiantum* fern with black shining petiole are beautifully arranged to impart appearance of a maiden's hair hence also called as **maiden hair fern.** In *Adiantum*, whenever its leaf-tip comes in contact with soil, it develops adventitious roots and forms a new plant. Hence it is also called as **walking fern.**

The plant body (adult sporophyte)

2. Pteridophytes bear an independent sporophyte with vascular system. It develops from the diploid zygote after the process of fertilization and exhibits a great variation in form, size and structure.

3. All present day pteridophytes are herbaceous except few woody tree ferns like *Cyathea spinulosa* and *Diksonia* etc.

4. Plant body is differentiated into true stem, roots and leaves. However, in lower pteridophytes like psilophytales (e.g. *Rhynia*) and psilotales (e.g. *Psilotum*) true roots and well developed leaves are absent.

5. Leaves may be megaphyllous or microphyllous in nature.

6. Plants may be dorsiventral or radial in symmetry and bear dichotomously or laterally branched stems.

7. The roots are generally adventitious. Primary embryonic root usually short lived.

8. Steles in pteridophytes range from protostele, siphonostele to dictyostele. Companion cells are absent in phloem. Vessels are absent in xylem. However, in *Selaginella* and *Equisetum* primitive vessels are present.

9. Cambium being absent, secondary growth does not take place in most of the pteridophytes. *Isoetes* is an exception.

Reproduction

10. The diploid sporophytic plant body produces haploid spores inside the sporangia, which serve as a means of asexual reproduction.

11. Sporangia are either borne on stem i.e. cauline in origin or on leaves i.e. foliar. The leaves bearing sporangia are called as sporophylls.

12. The development of sporangium may be **eusporangiate** or **leptosporangiate.** The eusporangium develops from several sporangial initials (e.g. *Psilotum*, *Lycopodium*, *Selaginella*, *Equisetum* etc.). The leptosporangium develops from single sporangial initial and found in advanced types (e.g. *Marsilea*, *Pteris* etc.).

13. The sporangia in some cases may be produce in specialised structures called **sporocarps.**

14. The sporophyte produces spores that may be homosporous (*Lycopodium*, *Dryopteris*) or heterosporous (*Selaginella*, *Salvinia*, *Azolla*).

15. The sporophylls may be scattered on the plant or restricted to particular regions called strobili or cones. Sometimes sporangia are present in groups called **sori.** Sorus may be protected by false indusium (e.g. *Pteris*) or true indusium (e.g. *Dryopteris*).

Gametophyte

16. Spores germinate to produce haploid gametophytic structures.

17. Homosporous pteridophytes generally bear monoecious prothalli. Heterosporous types bear unisexual (dioecious) gametophytes. Microspores produce male gametophytes and megaspores produce female gametophytes. When gametophytes are retained within original spore case it is called as **endosporic** (e.g. *Selaginella*, *Isoetes* and *Marsilea*). When gametophytes grow upon the soil and form independent plants, it is called **exosporic** (e.g. *Psilotum*, *Pteris*, *Lycopodium*).

18. The gametophytes are generally highly reduced in heterosporous pteridophytes e.g. *Selaginella*, *Marsilea*, *Azolla*.

Sex organs

19. The sex organs may be embedded or of projecting type.

20. Male sex organs are called as **antheridia** and female sex organs are called as **archegonia**. Gametophyte

STILL INTERESTING

- *Salvinia* is a rootless pteridophyte. Root like structures are modified leaves.
- *Alsophila* is tallest pteridophyte.
- The aquatic weed *Salvinia* is called **Sorrow of Kashmir.**
- Water fern *Azolla* is smallest pteridophyte.
- *Adiantum caudatum* is called walking fern.
- *Osmunda regalis* is Royal fern.
- *Onicum* is called carrot fern.

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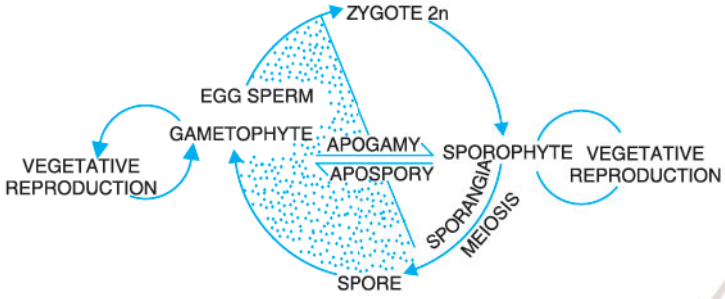

Fig. 21. Life cycle of homosporous pteridophyte.

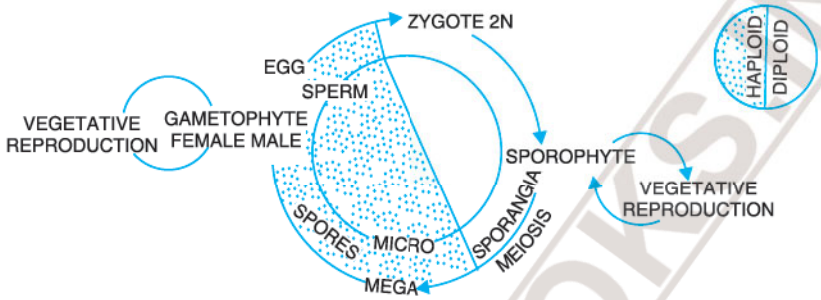

Fig. 22. Life cycle of heterosporous pteridophyte.

formed from homosporous type are **monoecious**. Heterosporous types are dioecious.

21. At maturity, each antheridium is a globular structure. It bears an outer sterile jacket enclosing a mass of androcytes. Each androcyte forms a motile sperm or antherozoid.

22. The archegonia have invariably four longitudinal rows of neck cells whose height varies from two to six cells, The neck canal cells vary from one (e.g. *Selaginella*) to 14 (e.g. *Lycopodium*). The venter encloses the egg and venter canal cell.

23. Sexual reproduction is of **oogamous** type.

24. For fertilization water is required.

Embryogeny

25. Zygote forms embryo, which remains attached with gametophyte and gets nourishment during its early stages.

26. When the axis of embryo faces inwards i.e. towards the base of archegonium, development is called **endoscopic** or axis of embryo is directed towards the neck of archegonium it is called as **exoscopic.** Examples of endoscopic development are *Lycopodium*, *Selaginella* and *Isoetes* and of exoscopic development are *Psilotum*, *Equisetum* and *Ophioglossum*. Development may be **lateral** *i.e.* when axis of embryo is at right angle to the long axis of **archegonium** *(e.g. Marsilea, Pteridium* and *Pteris).*

27. All the pteridophytes show heterologous and diplohaplontic type of alternation of generations.

Apospory. It is production of a gametophyte directly from the vegetative cells of the sporophyte. Spore formation is eliminated here. The gametophytes developed in this way are diploid instead of normal haploid ones.

Apogamy. It is the formation of a sporophyte directly from the vegetative cells of the gametophyte. Thus sporophyte is produced without gametic union, without fertilization.

Apospory is more widespread than apogamy.

CLASSIFICATION OF PTERIDOPHYTA

Pteridophytes are classified into four classes :

1. Division – Psilophyta (whisk ferns) : These are most primitive land plants. The body is very simple with green upright branches and an underground stem-rhizome. Roots and true leaves are absent. These plants grow in warmer parts of the world e.g. *Psilotum.*

2. Division – Lycopodophyta. Plants are known as **club mosses**. They are small and grow close to ground in forests. The cones are produced near the tips of branches. The plants grow abundantly in mountainous parts. e.g. *Lycopodium, Selaginella.*

3. Division - Equisetophyta. These are also known as **horse tails.** The plants possess hollow, jointed, upright branches which grow up from underground stem. Leaves are not large an green. Whorls of small scale like leaves develop from nodes on the branches. These plants produce sporophylls that are organised in cones. The cones develop at the tips of some of the upright branches e.g. ***Equisetum.***

4. Division – Filicophyta (Ferns). This includes true ferns such as ***Adiantum, Pteris, Nephrolepis.*** Ferns have underground stem which produce leaves above the ground. On the lower surface of the leaves small brown dots are seen. These are sori which are groups of sporangia containing spores.

Life cycle in pteridophytes

In the life history of pteridophytes, **there is a typical heteromorphic alternation of sporophytic and gametophytic generations** i.e. these two generations alternate with each other regular succession—sporophyte to gametophyte and gametophyte to sporophyte.

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Sporophytic or asexual generation is diploid. The majority of pteridophytes produce only one kind of spores (i,e. **homosporous**). Their gametophytes are **exosporic**, form thin plate of cells and are confined to humid conditions. Remaining members of pteridophyta bear two kinds of spores **heterosporous**. Larger spores are called as **megaspores** and smaller are called **microspores.** Microspores produce male gametophytes and megaspores form female gametophytes. The gametophytes of heterosporous forms initiate within spore case i.e. **endosporic** in nature. The male gametes (antherozoids) are produced in antheridia. They are flagellated, motile and in water for fertilization.

The female gametes (eggs) are non-motile and are present in venter portion of archegonium. Fusion occurs between sperm and egg to form diploid **zygote** (oospore). The gametophyte generation gives rise to sporophyte by gametic union and sporophyte gives rise to gametophyte by forming haploid spores after meiosis.

Rarely, cytological alternation of generations is hampered due to the formation of gametophyte spores **(apospory)** and also sporophyte directly from the vegetative cells of gametophyte without gametic union **(apogamy).** Egg may also develop apogamously into sporophyte and the process is called as **parthenogenesis.**

FERN (*DRYOPTERIS*)

Dryopteris is an evergreen fern and is common in moist woods and deep shaded ravines. It is found at moist and shady places. It often attains a height of 2 ft.

Morphology

1. The plant body of *Dryopteris* is differentiated into roots, stem and leaves. Leaves or fronds are the only aerial parts of plant body.

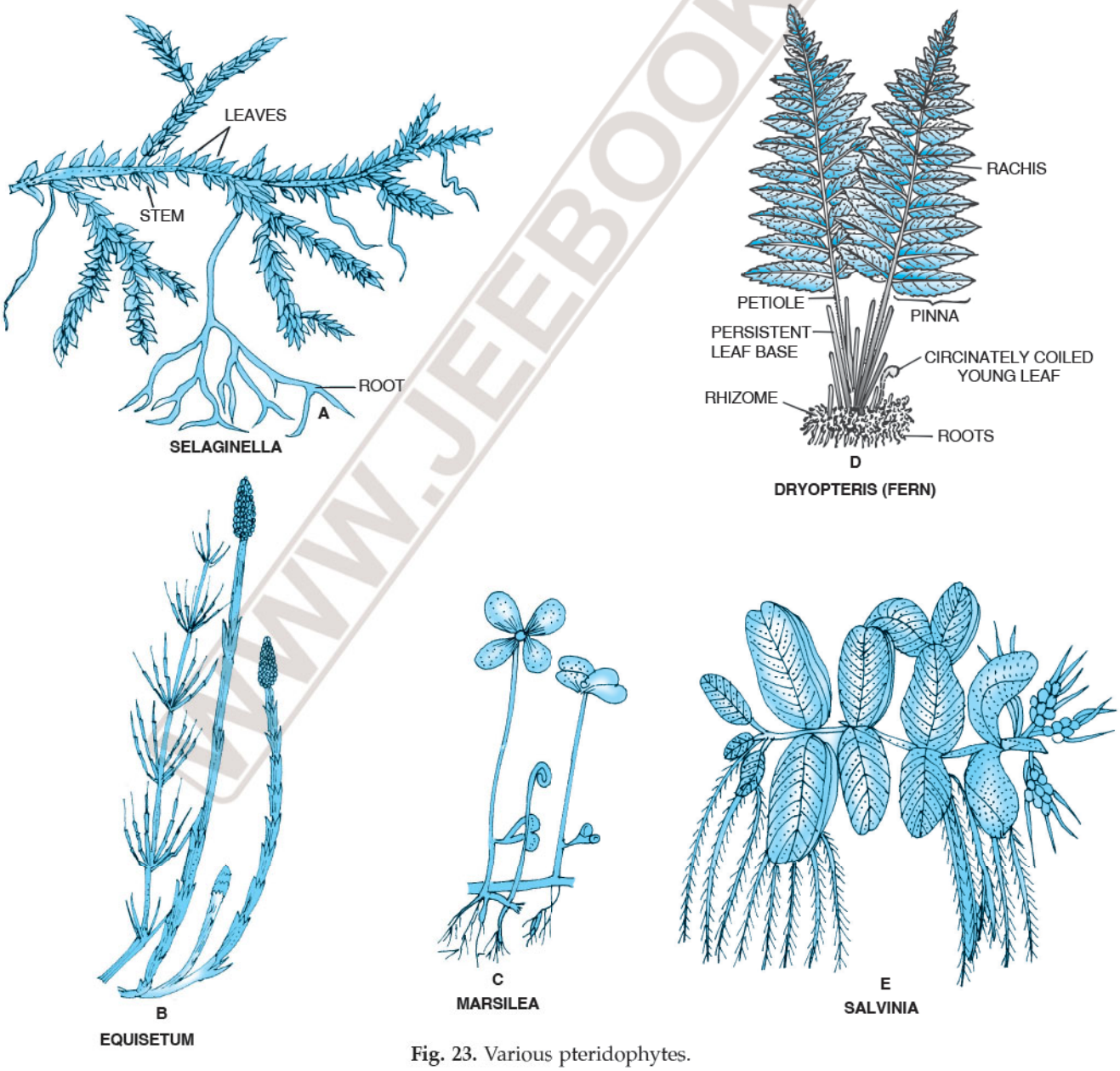

Fig. 23. Various pteridophytes.

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2. Stem is represented by underground rhizome. It is unbranched, obliquely placed and known as root-stock.

3. Rhizome is densely clothed with membranous scales or ramenta.

4. Persistent basal part of dead old leaves are present on the older parts of rhizome.

5. Leaves are large, compound and look like branch hence the name **frond.** They are pinnately compound.

6. They are completely or incompletely bipinnate and imparipinnate type.

7. Young leaves are circinate *i.e.* coiled inwards on the upper surface.

8. The pinnae are smaller towards the base and apex but longer in the centre. Each pinnule shows the presence of mid-rib and furcate type of lateral veins. Each leaf has a short stalk called petiole. The pinnae develop on main stalk called **rachis** which is the continuation of petiole.

9. Adventitious roots are present in irregular intervals from the rhizome. They are sparingly branched and possess root cap.

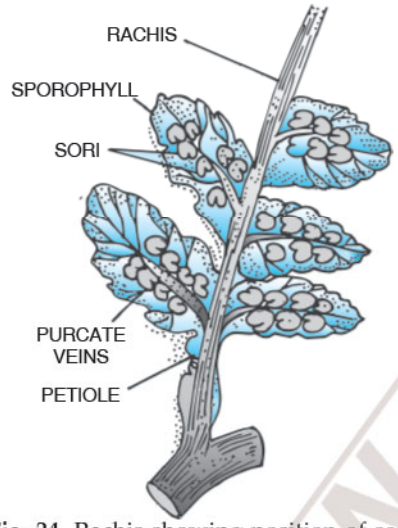

Fig. 24. Rachis showing position of sori.

Sporophyll

1. Leaflets with sporangia are known as sporophylls.

2. Sporangium bears large number of spores.

3. The spores are of one type only *i.e.* homosporous.

4. The sporangia are aggregated in groups called **sori.**

5. The sori are formed on the under surface of leaflets and are kidney shaped in outline.

6. In the beginning they are green in colour, however, they turn brown at maturity.

7. Each sorus is protected by membranous covering known as **true indusium** which originates from placenta. These sori are connected with small veins.

Sporangium

1. Each sporangium consists of a stalk and capsule.

2. The stalk is made up of 2-3 rows of elongated cells.

3. The capsule is oval and biconvex in shape.

4. The capsule is composed of single layer of thin walled cells (stomium) except annulus.

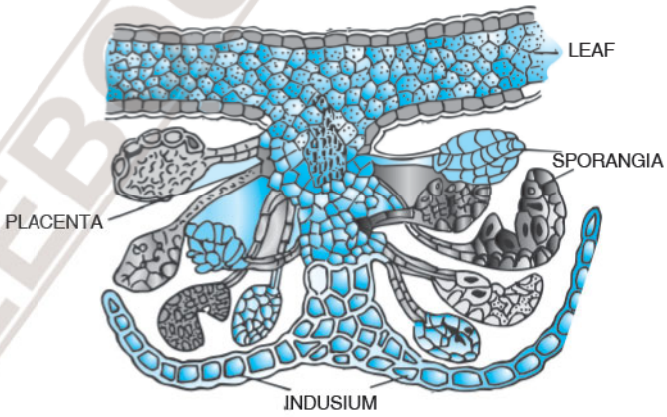

Fig. 25. V.S. Sporophyll to show sporangia.

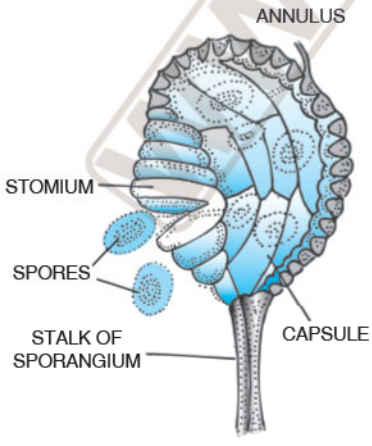

Fig. 26. A single sporangium.

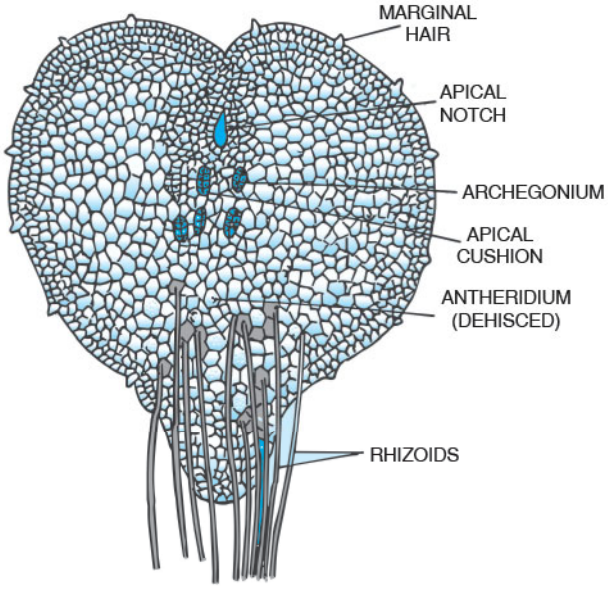

Fig. 27. Fern prothallus.

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5. The inner tangential and two radial walls comprising the annulus are comparatively thin.

Spore

1. The spores are minute, dark brown and tetrahedral in shape.

2. Spore is made up of two layered walls.

3. Outer wall is thick, rough, cuticularised and known as exine.

4. Each spore is uninucleate and has some stored food inside it.

Prothallus

1. The prothallus is green and heart-shaped.

2. The margin is thin and single layered while central part is thick and many layered called **cushion.**

3. The prothallus lies flat on the ground and bears many unicellular **rhizoids** on its lower surface.

4. On the under surface **antheridia** (male sex organs) and **archegonia** (female sex organs) are borne.

5. Antheridia develop amongst the rhizoids and archegonia near the groove.

Antheridium

1. Antheridia are small with spherical or oval body.

2. Its wall is made up of four cells *i.e.*, cap cell, two ring cells and a basal cell.

Archegonium

1. Archegonium is a small flask shaped structure.

2. Lower swollen venter is embedded in the prothallus.

3. Neck is made up of four vertical rows.

4. Archegonium contains an egg and a venter canal cell.

Fertilization

Antherozoids swim in water by their cilia. Venter canal cell and neck canal cell disintegrates in the archegonium to produce mucilage and malic acid. Attracted by these chemicals, many sperms enter the neck and pass down into the venter. One of the sperms fuses with the egg to form zygote. It covers itself with a cell wall and is called **oospore**.

The oospore divides and redivides to give rise to an embryo. The early stages of embryo development are dependent on prothallus for food and water. However, with the development of green leaf and root and with decay of prothallus, sporophyte develops into an independent body.

Ferns and mosses have been considered **amphibians among plants**. Bryophytes (mosses) and pteridophytes (ferns) need water for the movement of flagellated male gametes (sperms). So, they need water at the time of fertilization. In this respect, they resemble with amphibians of animal kingdom. Amphibians also need external surface of water for male gametes to swim to fuse with the female gametes (eggs) outside their body.

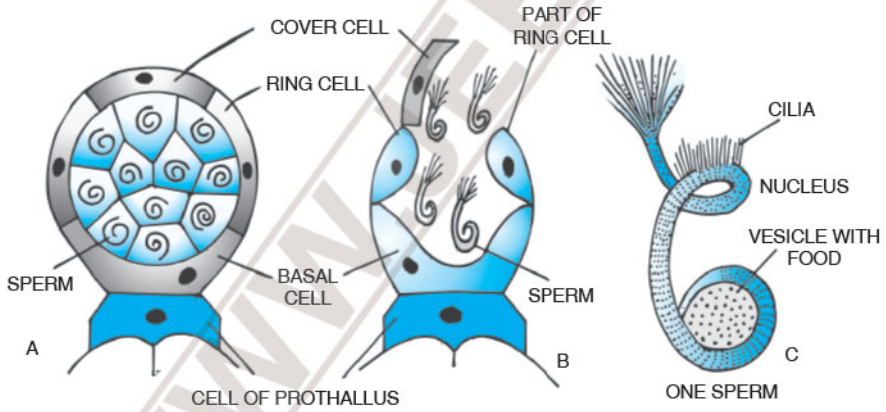

Fig. 28. A. Antheridium; **B.** Dehiscence; **C.** An antherozoid.

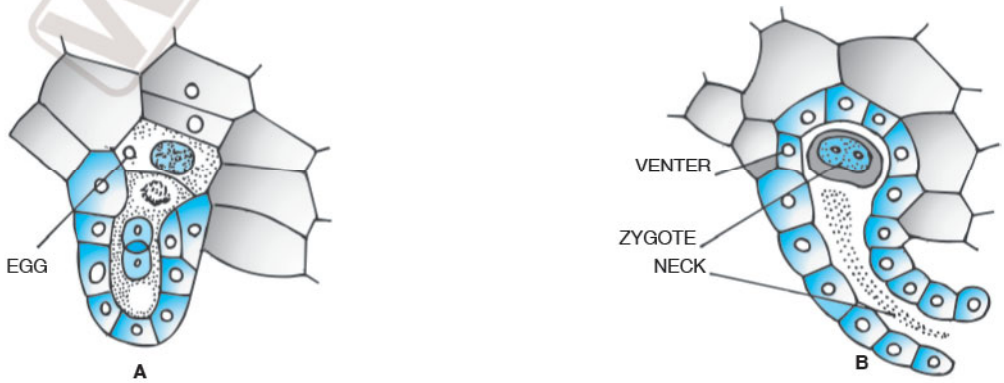

Fig. 29. A. L.S. Mature archegonium; **B.** L.S. Archegonium showing zygote.

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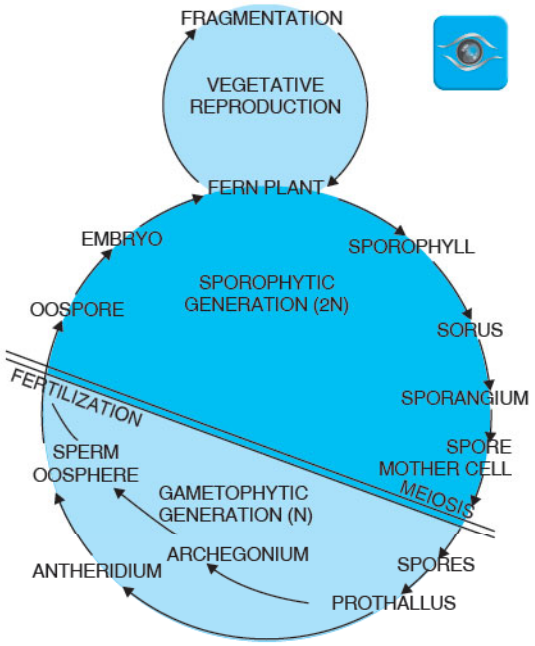

Fig. 30. Graphical life cycle of a fern.

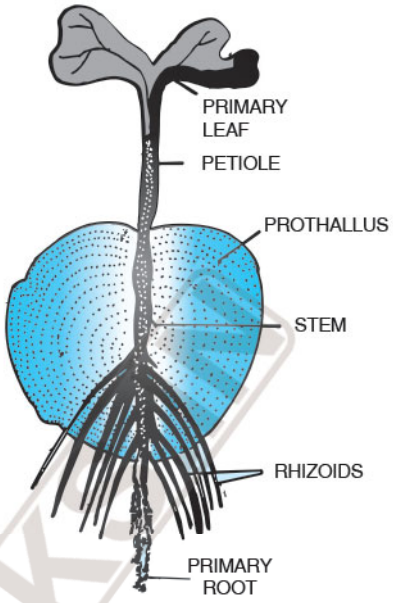

Fig. 31. Erect young sporophyte with roots developing from flat, heart shaped gametophyte (prothallus).

Table 14. Differences between homosporous and heterosporous pteridophyte.

Character	Homosporous pteridophyte	Heterosporous pteridophyte
1. Spores	All the spores are of one type.	Spores are of two types *i.e.* microspores (small) and macrospores (large).
2. Sporangium	Spores are formed in side sporangium.	Microspores are formed in microsporangia and megaspores are formed in megasporangia.
3. Gametes	Spores on germination forms prothallus on which gametes are borne.	Male gametes are formed from male gametophyte due to germination of microspore. Macrospore gives rise to female gametophyte.
4. Example	Ferns like *Pteridium, Dryopteris, Pteris.*	*Selaginella, Salvinia.*

DID YOU KNOW

- **Protostele** bears a core of xylem surrounded by phloem and pericycle and is the simplest type of stele.
- **Siphonostele** is non-vascularized in the centre which is occupied by pith.
- In **dictyostele**, amphiphloic siphonostele bears overlapping leaf gapes which give the vascular strand the appearance of hollow network. Individual strands are known as **meristeles**.
- Atactostele bears number of scattered vascular bundles as in monocots.
- In **radial bundles**, xylem and phloem bundles are found alternatively. They are found in roots.

ADDITIONAL USEFUL INFORMATIONS ABOUT PTERIDOPHYTES FOR COMPETITIVE EXAMINATIONS

- *Pteridophytes are vascular, non-flowering plants.*
- *Soral covering in ferns is called* ***indusium.***
- *Vernation is arrangement of leaves in bud condition.*
- *Unbranched erect axis is called* ***caudex.***
- *Brown scales are called* ***ramenta.***
- *Plant body is differentiated into true stem, root and leaves in pteridophytes.*
- *Seeds are not formed in pteridophytes.*
- *Strip of thickened cells on annulus is called* ***annulus.***
- ***Stomium*** *is the area on sporangial wall from which spores dehisce.*
- *Gametophytic stage in ferns is represented by gametophyte.*
- *Tallest fern is* ***Alsophila.***

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- ***Equisetum*** *is also called horse tail.*
- ***Salvinia*** *is rootless pteridophyte.*
- ***Stelar theory*** *was given by* ***Tiegham*** *and* ***Doulat*** *while studying pteridophytes.*
- ***Selaginella, Isoetes, Marsilea*** *and* ***Salvinia*** *are heterosporous pteridophytes.*
- *When many sporangial initials take part in the development of sporangium, it is called* ***eusporangiate*** *type of development. When single cell forms sporangium, development is called* ***leptosporangiate*** *type of development.*

GYMNOSPERMS—SEED PLANTS WITHOUT FLOWERS (PLANTS WITH NAKED SEEDS)

Gymnosperms along with angiosperms are included under **spermatophyta** (seed bearing plants). In gymnosperms ovules that mature into seeds are freely exposed. Following important events occur during the life cycle of a gymnosperm :

Habit, habitat and distribution

1. Angiosperms have about 2,50,000 named species as compared to near about 900 living species of gymnosperms. Though, they form comparatively a small group, yet they constitute ancient group of plants.

2. The gymnosperms are woody plants which do not bear flowers, but bear seeds on the inner side of scale like leaves that are usually arranged spirally to form cone.

3. The four orders of gymnosperms with living members are Cycadales, Coniferales, Ginkgoales and Gnetales. Other orders are known only from fossil records.

4. Xylem in gymnosperms is composed only of tracheids and wood parenchyma. Wood fibres and vessels are absent. Thus the gymnosperms are **soft woods** rather than **hard woods.**

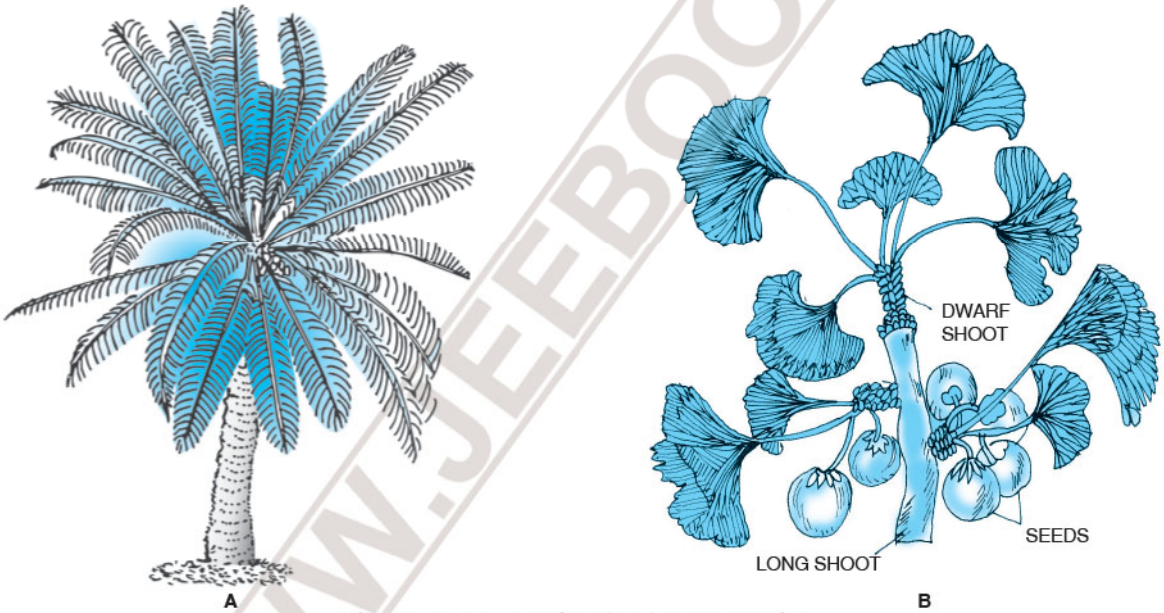

Fig. 32. A. *Cycas* (a female plant); **B.** *Ginkgo.*

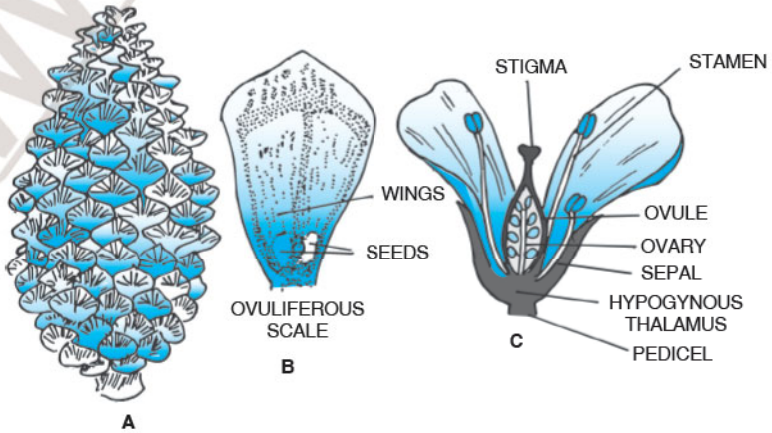

Fig. 33. Seed habit in gymnosperms and angiosperms; **A.** Female cone of *Pinus*; **B.** Megasporophyll of *Pinus* bearing naked seeds; **C.** V.S. of Mustard flower to show ovules are covered with ovary wall.

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5. Cycads found in warm weather have either short, tuberous, underground stems or erect, cylindrical stems above the ground with their large, compound divided leaves. They resemble miniature palm trees for which they are usually mistaken. They are extensively grown in gardens, college campus etc. as ornamental plants. *Cycas circinalis* a cultivated cycad also grows wild in southern India.

6. Cycads always bear two kinds of trees, one of which produces male cones and other produces ovules. Plants are thus dioecious.

7. Conifers include pine, cedar, spruce, fur and red wood trees. Conifers form the largest group of 500 species. They constitute the largest dominant vegetation in cooler northern areas of Europe, Asia and North America. They are found in Himalayas (constitute the upper timber line). The needle-like leaves of these evergreens are specially adapted for xeric conditions. Conifers bear two kinds of cones, one producing pollen, other producing eggs.

8. Conifers are economically important in the sense they produce wood used for con-struction and paper manufacture etc. *Araucaria*, grows nicely at plains with warmer climate, is one of the finest ornamental plant for gardens etc. Pine nuts are edible. Resin secreted by plants like *Pinus* is used for the preparation of tar and turpentine etc. Berries of juniper are used for flavouring the alcoholic beverage like gin etc.

9. Geological studies reveal that gymnosperms appeared in palaeozoic era some 200 million years ago. Alike present day gymnosperms, few gymnosperms appeared during past geological ages. This has been confirmed by study of fossils. So the gymnosperms are more **ancient than angiosperms**. Certain primitive gymnosperms are represented both in living and fossil form towards the end of mesozoic era, during cretaceous, gymnosperms gradually gave way to angiosperms structure.

10. Gymnosperms are mainly woody plants represented by trees, shrubs etc. They are **perennials**. **Sequios are one of the tallest trees and also longest living tree.** *Ginkgo*, the **maiden hair tree** which is found only as single species called as **living fossil.** *Ephedra* is mainly found in desert regions. An unusual gymnosperm *Welwitschia*, found in Africa, most of this plant exists underground and bears two large strap like leaves.

11. They bear tap roots. They may exhibit association with algae to form coralloid roots (*Cycas*) or with fungus to form mycorrhizal roots (*Pinus*).

12. Leaves may be of one kind or two kinds *i.e.* foliage leaves and scale leaves. Leaves may be reduced (*Ephedra*), needle like (*Pinus*) or large and pinnately compound (*Cycas*).

13. The **ovules** are **orthotropus** and covered by a single integument which is usually made up of outer fleshy, middle stony and inner fleshy layer.

14. The female gametophyte is constituted by haploid endosperm on which 2-8 archegonia are present. Neck canal cells are absent.

15. Sexual reproduction is of oogamous type.

16. Male cones bear microsporophylls on which microsporangia are borne.

17. Microspores (pollen grains) are formed in the microsporangia and they lead to the development of male gametophyte.

18. Pollen tube grows through the female gametophyte and reaches near the archegonium. Syngamy occurs and oospore (2n) is formed.

19. Oospore forms embryo. **Polyembryony** is common in gymnosperms.

20. Ovules are transformed into seeds.

21. Seeds contain two to many cotyledons which on germination gives rise to diploid plant.

Classification of Gymnosperms

1. **Division** — Pinophyta (Conifers)
2. **Division** — Cycadophyta (Cycadophyta)
3. **Division** — Ginkgophyta (*Ginkgo*)
4. **Division** — Gnetophyta (Gnetophytes)

PINUS

Habit

A mature plant of *Pinus* is a large tree growing upto 30-70 metres in height and is differentiated into thick columnar stem, leaves and roots. It is widely distributed in the hilly areas. *Pinus* grows on shallow soil presents on rocks and bears tap roots, which do not penetrate very deep in the soil. The main trunk represents the stem which is cylindrical and branched. The branches are confined to the upper part of stem while lower columnar stem appears naked (Fig. 34).

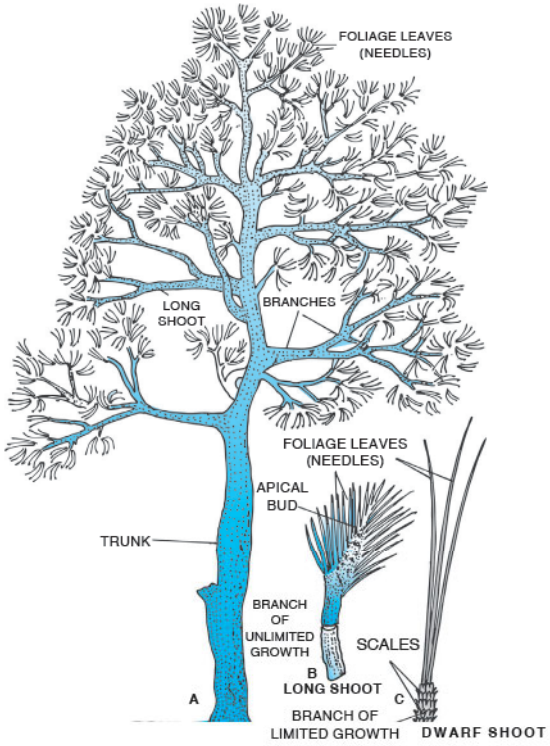

Fig. 34. *Pinus longifolia* (*P. roxburghii*): **A.** External feature of tree; **B.** a long shoot; **C.** a dwarf shoot.

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The *Pinus* plants are the source of different commercial products like timbers, resins, raft paper, chilgoza (seed of *P. gerardiana*) etc.

External Morphology

1. Mature plant of *Pinus* is large tree and is differentiated into thick columnar stem, evergreen leaves and roots.

2. The main trunk represents the stem which is cylindrical and branched.

3. The branches are confined to upper part of the stem while the apical bud of main stem grows faster than the apical buds of branches.

4. The branches are arranged in acropetal order thus giving the pyramid or conical shaped appearance to the tree.

5. The branches are of two types :

(a) Long shoots or branches of unlimited growth.

(b) Dwarf shoots or branches of limited growth.

Long shoot

1. There are normal types of branches present on the main stem and bears terminal but at its apex, hence unlimited in growth.

Dwarf shoot (spur)

1. These branches develop on long shoot in the axile of scaly leaf.

2. They do not produce apical bud at their apex hence limited growth.

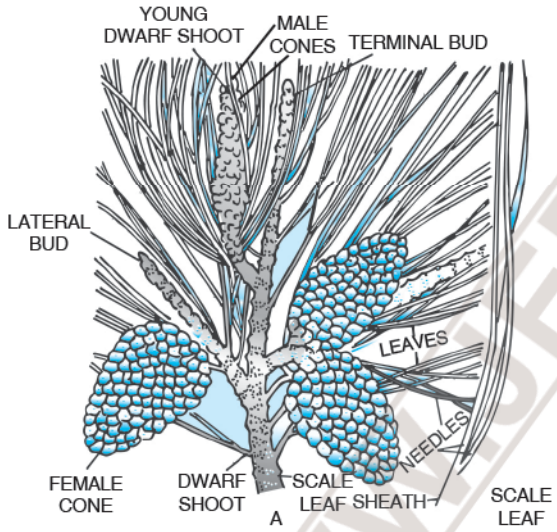

Fig. 35. A long shoot of *Pinus* bearing foliar spurs (Dwarf shoots); Male and female cones.

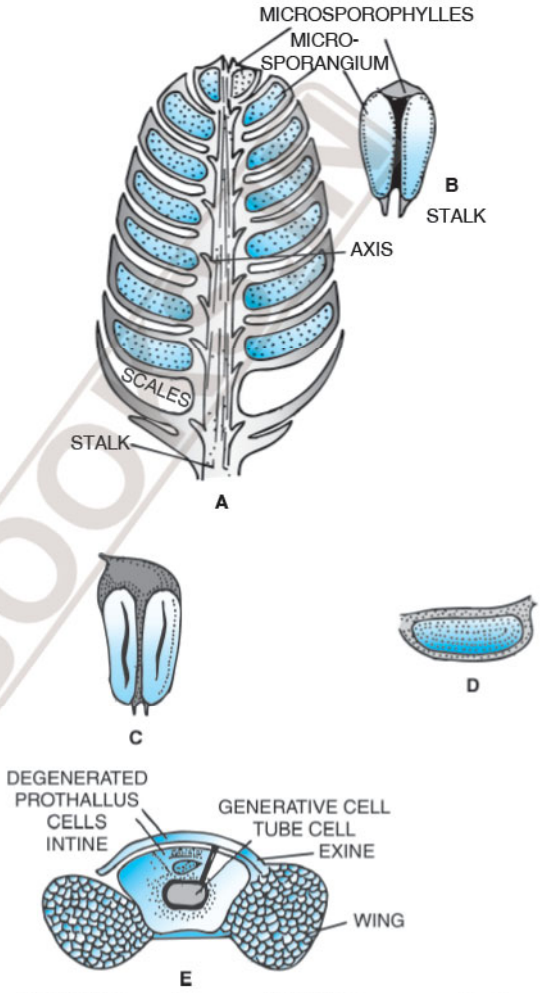

Fig. 36 **(A)** L.S. male cone; **(B-C)** Microsporophylls seen from ventral side; **(D)** Microsporophyll side view; **(E)** Germinated pollen grains.

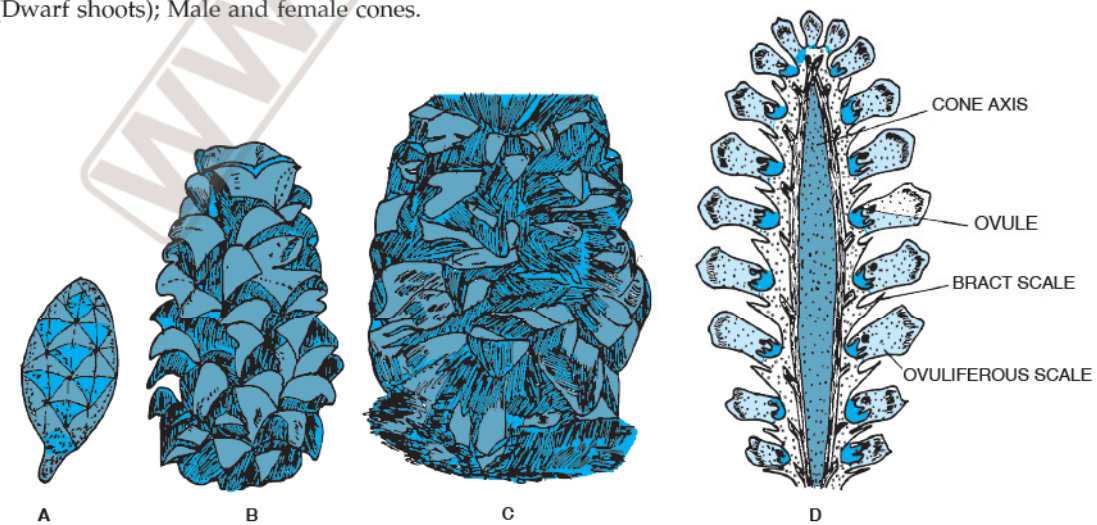

Fig. 37. **(A)** First year female cone; **(B)** Second year female cone; **(C)** Third year female cone; **(D)** L.S. female cone.

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3. The dwarf shoot bears foliage leaves at its apex.

4. The dwarf branch bears foliage leaves (needles) at its apex.

5. The foliage leaves and dwarf branches are surrounded by a scaly membranous sheath at the base which combine to form **spurs.**

Leaves

Leaves are of two types :

(a) Scale leaf

(b) Foliage leaf

Scale leaves

1. Scale leaves are brownish, membranous or scaly structure.

2. They are present on long shoot and are protective in nature.

3. They protect the younger parts of the plant like dwarf shoot, apical bud and male cones etc.

Foliage leaves (needles)

1. The foliage leaves are acicular in shape and commonly termed as needles.

2. Number of needles for a particular species are fixed for each foliage spur.

3. Needles are green, long and photosynthetic.

4. Their tender bases are covered by membranous sheath.

5. They are borne on dwarf branches which appear in the axil of scale leaf on long branches.

SEXUAL REPRODUCTION

Male cone

1. Male cone develops below the apical bud on long shoot in cluster.

2. Each male cone is 2-3 cm. long when fully mature.

3. A male cone has a central axis on which 60-125 microsporophylls which are arranged spirally.

Microsporophyll

1. Microsporophyll has a sterile apex and two pollen sacs (microsporangia).

2. Microsporophyll has a yellow sac like structures present on the ventral surface of microsporophyll.

3. Each microsporangium contains number of microspores or pollen grains.

Pollen grain (microspore)

1. It is spherical in shape.

2. It is surrounded by three layered wall.

3. The outer exine is found only on upper side of pollen grain.

4. Middle layer or mesine (exo-intine) covers the rest of pollen grain and expands to form two large balloon like **air sacs** or **wings.**

5. Innermost layer intine is very thin.

Female cone

It is present in the axil of scale leaf near the apex of young branch which stops growing further after the formation of female cones. Each shoot bears one to four female cones.

1. First year female cone is small, erect, ovoid, pale green structure with compactly arranged megasporophylls. It is about an inch in length.

2. The second year female cone is large, woody and reddish is structure. It is about 4-6 inches in length.

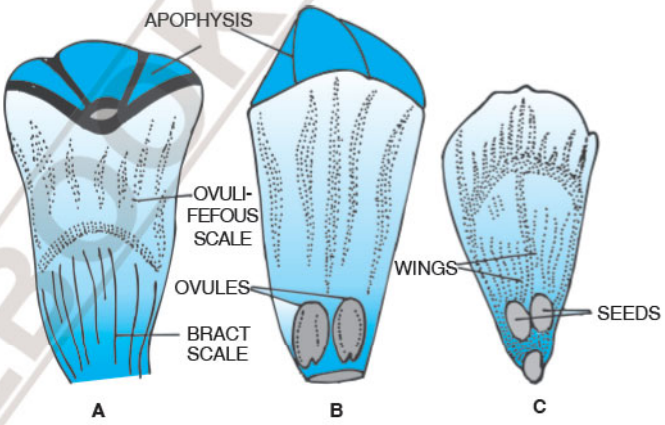

Fig. 38. Ovuliferous scale (Megasporophyll); **(A)** Under surface (adaxial); **(B)** Upper surface (abaxial); **(C)** With seeds.

3. On the central axis are borne two kinds of paired scales in spiral fashion (megasporophylls).

4. The lower scale of megasporophyll is thin membranous and small and called bract scale.

5. The upper scale is large, stout, woody and triangular in shape hence called ovuliferous scale.

6. Two naked ovules are borne on the upper surface of ovuliferous scale towards the end which is near the central axis.

7. Distal, sterile, broad part is called as **apophysis.**

Germination of pollen grain. The pollen grains start germinating within the microsporangium and produces partially developed male gametophyte consisting of two disintegrating male prothallial cells, a generative cell and a tube cell.

Germinating pollen grains are carried by wind to the female cone. The pollen tube enters into the tissue of ovule. At the time of fertilization, male gametophyte constitutes a pollen tube having a tube nucleus, stalk

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nucleus and two male gametes (Fig. 39). The stalk and tube nuclei disintegrate. The pollen tube discharges the male nuclei. One of the male gametes fuses with egg to form zygote.

Seed

The zygote (oospore) forms four embryos, only one matures. The ovule is transformed into seed. Approximately 15 months are required between pollination and fertilization. Cone formation to seed dispersal needs about two years. Seeds remain dormant for some time or may germinate immediately without undergoing resting period. Seed coat ruptures, radicle gives rise to primary tap root. Plumule forms shoot and grows upwards. *Pinus* constitutes embryo with many cotyledons. Sporophytic generation in *Pinus* is dominant and independent. It exceeds the reduced and dependent gametophytic generation.

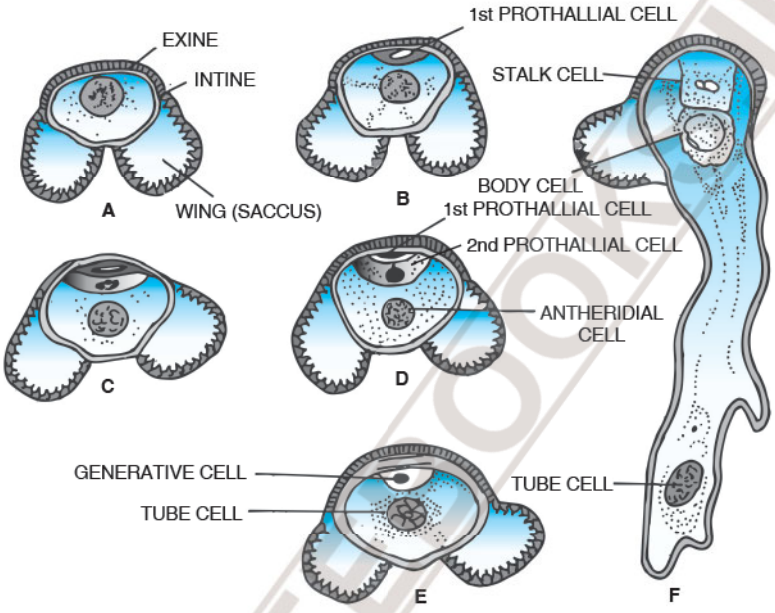

Fig. 39. Stages for the germination of microspore (development of male gametophyte) in *Pinus*.

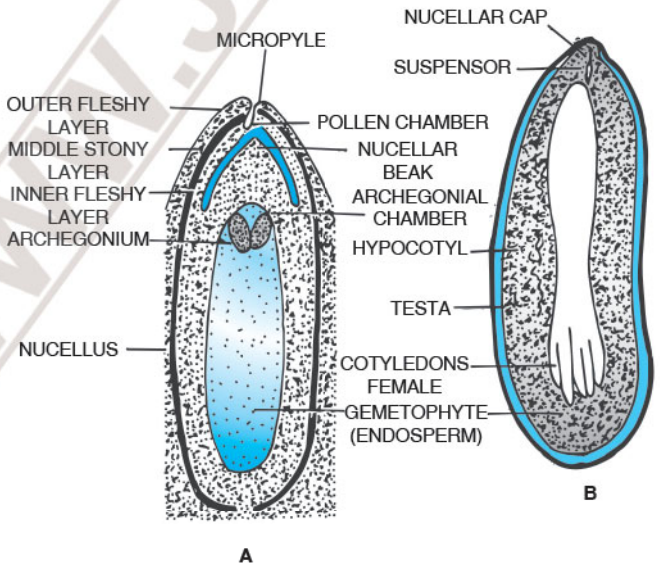

Fig. 40. *Pinus* **A.** L.S. of an ovule ready for fertilization; **B.** L.S. of a mature seed.

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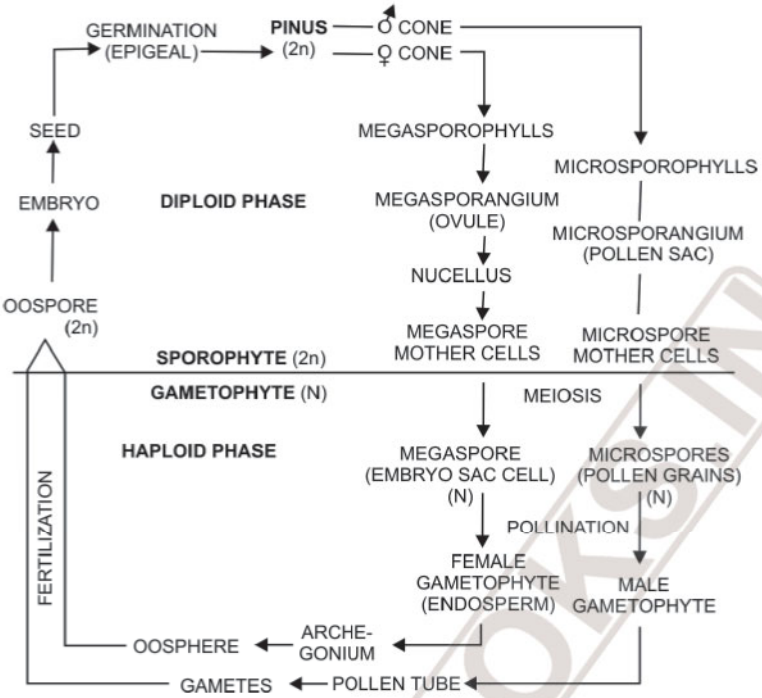

Fig. 41. Graphical life cycle of *Pinus*.

ECONOMIC IMPORTANCE OF GYMNOSPERMS

1. Ornamentals. Many gymnosperms which are native to other places, but are cultivated in Indian gardens as ornamental plants. Some of them include *Cycas revoluta, Cupressus sempervirens, Cupressus funiberus, Thuja occidentalis, Araucaria* species etc.

2. Food articles. Some gymnosperms yield many articles which are used as food directly or indirectly. *Cycas circinalis* yields a starch from its stem and seeds, which is called **"Sago".** The seeds of *Pinus gerardiana* **(Chilgoza)** are edible and very nutritious. Seeds of *Gnetum ulva* are also edible. Young leaves and inflorescences of **Gnetales** are eaten as vegetable. The seed kernel of *Ginkgo* is highly nutritious and is used as food in China and Japan.

3. Wood. Many gymnosperms are recognized for their valuable woods. Many species of *Abies* provide a light and useful wood utilized in making slippers. *Cedrus deodara* yields the strongest Indian timber resistant to white ants and fungal attacks. The twigs of *Juniperus* are burnt as incense in temples. The wood of *Picea smithiana* is used for railway sleepers. The wood of *Pinus roxburgii* is used as timber. The wood of *P. wallichiana* is superior to that of *P. roxburgii. Taxus baccata* yields a durable wood. *Cryptomeria japonica* yields a valuable light wood.

4. Medicinal value. The resin obtained from *Cycas rumphii* is applied to ulcers. The wood of *Cedrus deodara* possess diuretic and carminative properties and is used in pulmonary and urinary disorders, piles and rheumatism. The leaves of *Cupressus sempervirens* yield an essential oil which possess vermifuge properties. The resin obtained from *Pinus roxburgii* is used internally as stomachic and as a remedy for gonorrhoea. It is used externally for buboes and abscess. The seeds of *Pinus gerardiana* yield an oil which is applied as a dressing to wounds and ulcers. The species of *Ephedra* yield a drug called **Ephedrine** which is used against asthma and bronchial troubles. The seed oil of *Gnetum ulva* is used in rheumatism and for illumination.

5. Resin and oils. The wood of *Pinus roxburgii* is tapped for turpentine which is distilled to obtain resin and turpentine oil. Resin is also obtained from *Pinus wallichiana.* The leaves and wood of *P. insularis* yield an essential oil. Some gymnosperms yield medicinally important oil as described above.

6. Other uses. The leaves and wood of *Pinus insularis* are used as fuel. *Gnetum contractum* and *G. latifolium* are used as fish poison. Bark of *Gnetum gnemon* is utilized for making ropes. The seeds and stems of *Cycas revoluta* are often used in the preparation of wine in Japan. Fossil gymnosperms which were common and widely distributed during carboniferous period have contributed to the coal deposits. The wood of *Juniperus verginiana* (red cedar) is used for pencil making. The bark of *Tsuga canadensis* yields tannin which is used in tanning hides. *Abies balsamea* yields **Canada balsam.**

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ADDITIONAL USEFUL INFORMATIONS ABOUT GYMNOSPERMS FOR COMPETITIVE EXAMINATIONS

- *Gymnosperms are naked seeded plants.*
- *In Pinus, pollen grains are winged.*
- *Dwarf shoot arise at the axil of bracts on long shoot.*
- *The ramnent nucellar tissue present within the seed covering of embryo is called* ***perisperm.***
- *Transversely oriented conducting parenchyma tissue of pine leaf is called* ***transfusion tissue.***
- *All gymnosperms bear* ***unitegmic*** *orthotropous ovules.*
- *Cycas wood is* ***mano*** *and* ***monoxylic****, where wood of Pinus is* ***pycnoxylic.***
- *The only gymnosperm showing limited growth is Welwitschia (45 cm. tall).*
- *Xylem lacks* ***vessels*** *in gymnosperms (non-porous). Vessels have been reported in Gnetum, Ephedra and Welwitschia.*
- *In gymnosperm* ***endosperm*** *is haploid and develops before fertilization.*
- *About two hundred million years ago, the gymnosperms formed the dominant vegetation on the earth.*
- *Ginkgo biloba is called* ***living fossil.***

ANGIOSPERMS—FLOWERING PLANTS

HABIT AND HABITAT

Angiosperms or flowering plants constitute the largest (12,500 genera and 2,50,000 species), the dominant and the economically most important class in the plant kingdom. They include trees, shrubs, vines and herbs adapted to almost every kind of environment. They are primarily land plants but some **hydrophytes** (*Hydrilla*, water lilies etc.) have taken water secondarily and even ocean water (eel grass, *Zostera*).

Many angiosperms are xerophytes. They bloom in deserts also after the shower. They may behave as **ephemerals** in deserts. During short favourable season, they grow, flower and shed seeds. Some have become epiphytes (plants growing on other plants but do not take food and water from them) as orchids etc. Few act as parasites (*Cuscuta*), some are saprophytes (coral root orchid). One species of angiosperms has been noticed in hot springs at 60°C. Still others grow at high altitude of 6000 metres in the Himalayas. Some have been reported even at Antarctica.

DEVELOPMENT OF FLOWER AND FRUIT HABIT

The sporophytic plant of an angiosperm bears flowers which is the site of sexual reproduction. Flower is a modified shoot.

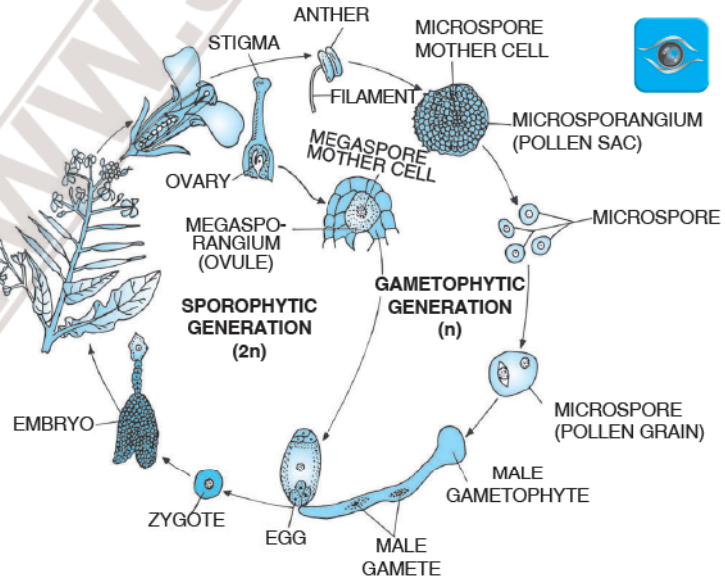

Fig. 42. Diagrammatic life cycle of an angiosperm.

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Flower bears sepals, petals, stamens and carpels which arise from thalamus. **Stamens** (androecium) and **carpels** (gynaeceum) constitute the essential parts of a flower. Non-essential parts are **sepals** (calyx) and **petals** (corolla). The sepals are usually green and petals are coloured and showy. Each stamen consists of stalk like **filament** and flattened globoid top called **anther**. The anthers produce the **pollen grains**. Carpel shows basal swollen ovary, middle elongated style and upper terminal stigma. The ovary contains ovules. The **functions** of a flower are :

(i) It is the part of a plant which helps in sexual reproduction.

(ii) It bears male sex organs *i.e.* stamens and female sex organs *i.e.* carpels.

(iii) Ovary after fertilization ripens into fruit which contains seeds and thus is responsible for continuation of the race.

Each stamen bears anther. The anther is a group of four **pollen sacs**. In pollen sacs, microspore mother cells or pollen mother cells undergo meiosis to form haploid pollen grains.

Ovary contains **ovules** borne on placentae. An ovule is a megasporangium enclosed by one or two integuments. In the nucellus of ovule one **megaspore mother cell** appears which after meiosis gives rise to four haploid **megaspores**. One of the megaspores form embryo sac (female gametophyte). Embryo sac bears eight nuclei. Micropylar egg apparatus contains two synergids and one egg. Lower three are called **antipodals** and central two constitute **polar nuclei**.

Pollen grain migrates to stigma of carpel by a process called **pollination**. Pollination is of two types : (a) self pollination and (b) cross pollination. Cross pollination can take place by agents like wind, water, insects, birds, bats and even humans. Insect pollinated plants (**entomophilous**) are generally showy, bear nectar and scent etc. Insects are mainly responsible for cross pollination and get in return nectar and edible pollen etc. As compared to angiosperms gymnosperms are dependent upon wind only for pollination.

The pollen grain which germinates on stigma forms a **pollen tube** and carries two sperm nuclei (**male gametes**) and tube nucleus. One of the male gametes fuses with egg to form **zygote**. The other male gamete fuses with two polar nuclei to constitute triploid **primary endosperm nucleus**. This phenomenon is called **double fertilization**. Primary endosperm nucleus gives rise to triploid **endosperm**.

Zygote forms embryo. Sepals, petals, stamens, style stigma wither at the time of fruit formation. **Fruit** is ripened ovary. The seed contains dormant embryo along with food material in endosperm or cotyledons.

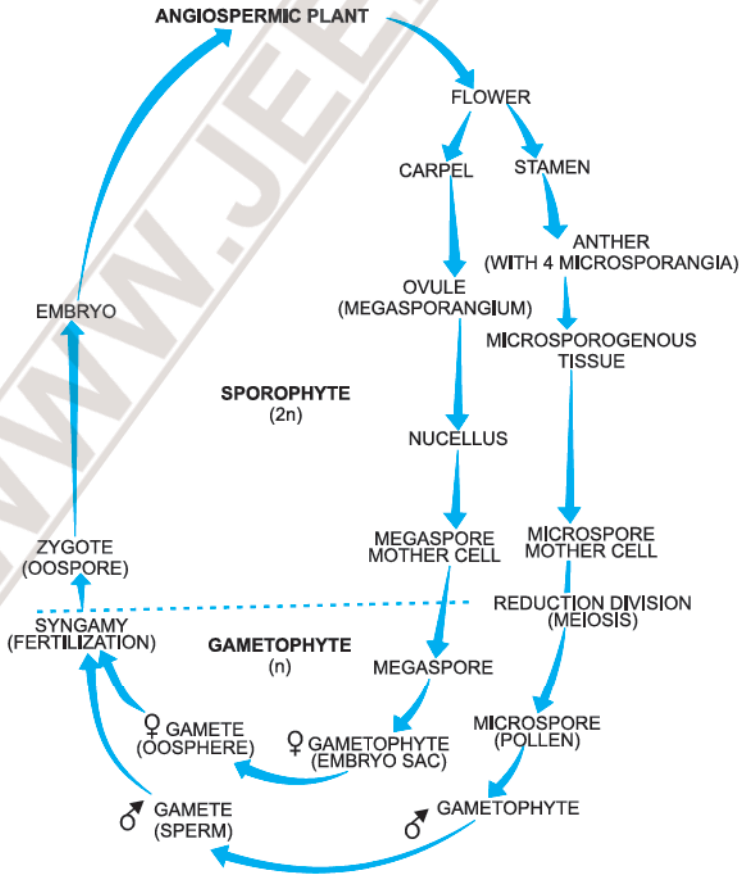

Fig. 43. Graphical life cycle of an angiospermic plant.

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MONOCOTS AND DICOTS

Two subclasses of angiosperms are named as **Dicotyledons** and **Monocotyledons.** They have been mainly distinguished on the basis of the number of cotyledons (food storing leaf-like structures in seed). Dicots bear two cotyledons in their seeds. On the other hand, monocots have only one cotyledon in their seeds. Other differences in dicots and monocots have been illustrated in Figs. 18 & 19 of chapter 6. Along with other differences dicots may bear tap roots, adventitious roots or both. Monocots show only adventitious roots.

The dicots are more abundant than monocots. More than 200,000 species of dicots and 50,000 species of monocots have been described. Many useful monocot plants are bamboos, grasses, sugarcane, bananas, lilies, tulips, orchids, cereals (like wheat, rice, maize etc.), palms, *Ruscus*, *Asparagus*, onion, garlic etc. Dicots include plants of all kinds of trees, shrubs and herbs like apple, peach, cherry, cotton, carrot, melon, cucumber. They provide wood, spices, pulses, fruits, vegetables, beverages (tea, coffee) and several ornamental plants.

Table 15. Differences between Syngamy and Triple fusion.

Characters	Syngamy	Triple fusion
1. Definition	It is the fusion of male gamete with female gamete to form a zygote.	In angiosperms, second male gamete fuses with diploid secondary nucleus to form primary endosperm nucleus (triploid), it is called triple fusion.
2. Result	Forms zygote	Forms triploid endosperm.
3. Function	Zygote forms embryo. developing embryo.	Endosperm provides nourishment to

PRACTICE PROBLEMS – PLANT KINGDOM

1. Define gametic meiosis.
2. Write the importance of phycocolloids in cell walls of brown algae.
3. Name the male and female sex organs in *Funaria*. Also write the type of sexual reproduction present in Bryophytes.
4. Name the following :
   (a) Edible brown alga
   (b) Source of Iodine.
   (c) Source of alginic acid.
5. What is agar ?
6. What are the uses of algin ?
7. Why most of the ferns are found in moist areas ?
8. What are liverworts ?
9. What is isogamy ?
10. How are vascular plants able to dominate the planet ?
11. Write any three similarities between moss and fern.
12. What are kelps ?
13. What is living fossils ? Give two examples.

ANSWERS TO PRACTICE PROBLEMS

1. The diploid organisms undergo the process of meiosis prior to sexual reproduction to form haploid gametes. This type of meiosis is called gametic meiosis.
2. Phycocolloids prevent desiccation and freezing in summer and winter.
3. **Male sex organ**– Antheridium
   Female sex organ – Archegonium
   Type of sexual reproduction– Oogamous
4. (a) *Laminaria* (b) *Fucus* (c) *Laminaria*
5. Agar is non-nitrogenous gel like substance obtained from red alga *Gelidium.*
6. (a) Algin is used as food.
   (b) It is used for making smooth ice creams.
   (c) It is used in textile industry and as gelling agent in pharmaceutical industry.
7. Ferns need moisture for fertilization. Sperms are flagellated and swim in water.
8. Liverworts are flat, green thallus attached to ground by the rhizoids. Sex organs are stalked. However, in *Riccia*, sex organs are embedded in thallus.

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9. When fusing gametes are morphologically and physiologically similar, type of sexual reproduction is of isogamous type.
10. Vascular plants dominate due to :
    (a) Presence of well developed vascular tissue.
    (b) Due to presence of mechanical tissue.
    (c) Due to presence of cutin in living tissue and suberin in dead tissue.
    (d) Well developed root system.
11. (a) Oogamous type of sexual reproduction.
    (b) Sperms are flagellated.
    (c) Water is required for the process of fertilization .
12. Kelps are giant brown algae.
13. An organism which is represented by long geographical record evidenced by its fossil and still found in living condition. **Examples :** *Ginkgo* and *Cycas.*

Table 16. Differences in reproduction of Gymnosperms and Angiosperms.

Characters	Gymnosperms	Angiosperms
1. Texture of sporophylls	Woody	Delicate
2. Structure	Cones	Flowers
3. Axis	Elongated axis for bearing sporophylls	Condensed and broad axis called thalamus to bear sporophylls
4. Arrangement	Sporophylls arranged spirally	Sporophylls arranged in whorls
5. Microsporophylls	Broad	Knobed threads to form stamens
6. Position of microsporangia	Abaxial	Terminal
7. Number of microsporangia	Many per microsporophyll	Four microsporangia (pollen sacs)
8. Placentae	Absent	Present
9. Funicle on ovules	Absent	Present
10. Tegmen	Unitegmic	Unitegmic or bitegmic
11. Female gametophyte	Massive	Small
12. Archegonia	Present	Absent
13. Ovules	Exposed	Present inside ovary wall
14. Double fertilization	Absent	Present
15. Endosperm	Haploid	Triploid
16. Seeds	Naked	Formed inside fruit

PLANT LIFE CYCLES AND ALTERNATION OF GENERATIONS

The fusion product of gametes is a diploid cell known as zygote. **Karyogamy** and **meiosis** takes place in zygote. Sometimes, karyogamy is immediately followed by meiosis in zygote, resulting in the production of haploid plant. In these two processes are separated in time and space, the zygote remains only the site for karyogamy and then the germination of zygote give rise to a diploid plant, and meiosis occurs at the time of spore formation in the diploid plant. The spores on germination produce haploid plants.

The distinct morphological and cytological stages through which the growth and development of an alga passes, constitutes a sequence of events, known as life history or life cycle. It means, the life cycle consists of two distinct phases : the somatic or morphological and the cytological. The morphological phase is considered as a **generation.** If, the life cycle of an plant **consists of two morphological phases : Haploid (gametophytic) and Diploid (sporophytic), regularly alternating with each other, the phenomena is termed as alternation of generations.**

In most of the simple forms of algae like blue green, *Protococcus*, *Scenedesmus* etc. there is no alternation of generations due to lack of sexual reproduction. When gametophytic and sporophytic stages are morphologically similar, it is called **isomorphic** alternation of generations (e.g. *Dictyota*, *Ectocarpus*), and if they are morphologically dissimilar, it is known as **heteromorphic** alternation of generations (e.g. *Laminaria*).

Plant life cycles

Considering both morphological and cytological aspects, five types of life cycles (life histories) have been recognized in algae : **haplontic, diplontic, diplohaplontic.**

(i) Haplontic life cycle : It is found in algae like *Chlamydomonas*, *Ulothrix*, *Spirogyra*, *Oedogonium* and *Chara.* There is a single dominant vegetative phase—the haploid gametophyte which produces gametes. Its asexual spores (mitospores), upon germination, helps in the multiplication of gametophytic generation without involving alternation of generations.

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Gametes produced in gametangia fuse to form zygotes (zygospores).

Meiosis takes place in zygotes at the time of its germination producing haploid spores called meiospores. Each meiospore germinates to form gametophytic plant. Thus, the only diploid stage is the zygote. In this type of life cycle, therefore, there is an alternation between a haploid vegetative gametophyte and a reduced diploid stage (zygote). So, there is no true alternation of generations morphologically, but cytologically, there is an alternation between a haploid and a diploid condition.

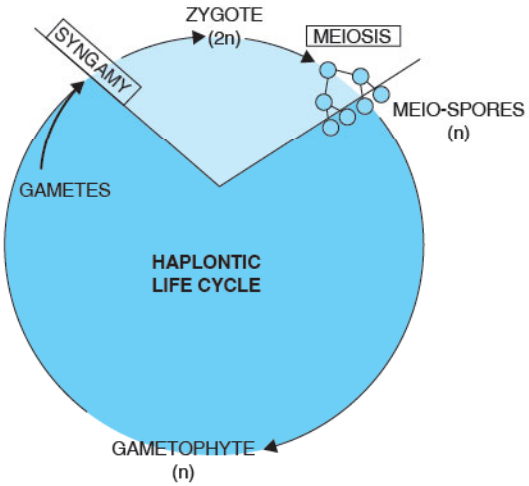

Fig. 44. Graphic representation of Haplontic life cycle.

(ii) Diplontic life cycle. It is found in all seed bearing plants i.e. **gymnosperms** and **angiosperms.** The dominant vegetative phase is diploid (sporophytic). The sporophyte bears sex organs which produce gametes. Thus meiosis occurs at the time of gamete formation (gametogenesis). The gametic fusion results in the production of zygote which gives rise to diploid sporophyte again

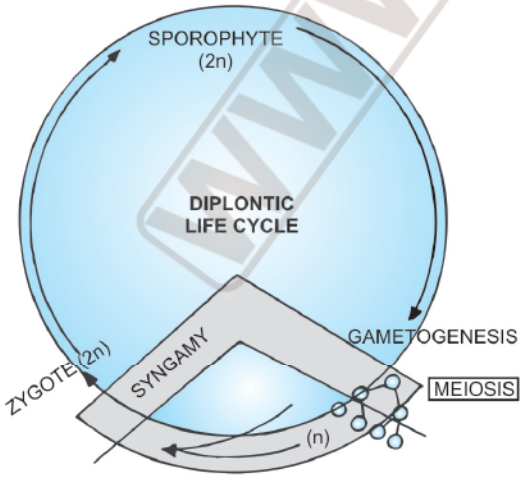

Fig. 45. Graphic representation of Diplontic life cycle.

through mitosis. In such cases, the haploid phase is represented by gametes only and the sporophytic plant alternates with the reduced haploid phase (gametes). Thus, there is no true alternation of generations morphologically, but cytologically, there is an alternation between a diploid and a haploid condition. The alga *Fucus*, shows diplontic life cycle.

(iii) Haplo-diplontic life cycle. This type of life cycle is found typically in algae like *Ectocarpus*, *Polysiphonia*, bryophytes, pteridophytes etc. It consists of two distinct vegetative phases alternating with each other which are different cytologically and functionally. The haploid gametophyte produces gametes in sex organs. The gametes fuse to form zygote which on germination give rise to diploid sporophyte. The diploid sporophyte is concerned with the production of spores after meiosis (meiospores). Thus, meiosis occurs at the time of spore formation (sporogenesis). The meiospores after germination give rise to gametophytic phase again. Therefore, there is true alternation between the gametophytic and sporophytic generation.

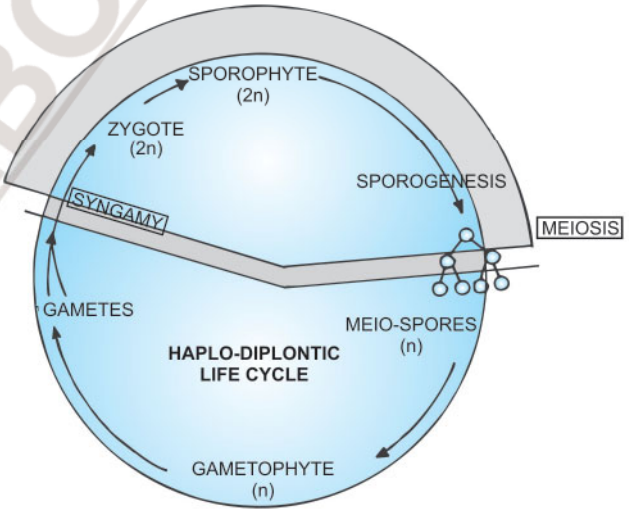

Fig. 46. Graphic representation of Haplo-diplontic life cycle.

In bryophytes and pteridophytes both phases are multicellular, however they differ in dominant phases. In **bryophytes**, a green, independent, thalloid or foliose phase is present in the form of haploid gametophyte. It bears a short lived multicellular sporophyte, which is partially or totally dependent on gametophyte for the purpose of anchorage and nutrition. However in **pteridophytes**, sporophyte is represented by a dominant, independent, photosynthetic, vascular plant body. It bears a short lived haploid gametophyte which is independent, multicellular, autotrophic or saprophytic.

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CHAPTER SUMMARY

- **Phylogenetic classification** system is based on evolutionary relationships between the various organisms.
- **Algae** are chlorophyll bearing simple, thalloid, autotrophic and aquatic organisms. Algae reproduce by vegetative, asexual and sexual methods.
- The members of chlorophyceae are commonly called as **green algae.**
- The members of phaeophyceae or **brown algae** are found mainly in marine habitats.
- The members of rhodophyceae are commonly called **red algae** due to presence of red pigment r-phycoerythrin in their body.
- **Bryophytes** include liverworts and mosses that are found in moist shaded areas of hills.
- The plant body of **liverwort** is thalliod.
- Common examples of **mosses** are *Funaria, Polytrichum* and *Sphagnum*.
- The **pteridophytes** include horsetails and ferns. The main plant body is sporophyte which is differentiated into true, stem, root and leaves.
- The **gymnosperms** are plants in which ovules are root enclosed by any ovary wall and remain exposed both before and after fertilization. Here, male and female gametophytes do not have an independent free living existence.
- In **angiosperms** or flowering plants, the pollen grains and ovules are developed in flowers. They are divided into two classes: the **dicotyledons** and **monocotyledons**. Due to involvement of two fusions of nuclei, angiosperms show the event of **double fertilization.**
- Different plant groups as well as individuals may show different types of life cycles- haplontic, diplontic or intermediate.

KEY TERMS

Annuals	:	Plants which live for one season and complete their life cycle in a single favourable season.
Anemophilous	:	Pollination which takes place with wind.
Antheridium	:	Male sex organ in algae, fungi, bryophytes and pteridophytes.
Archegonium	:	Female sex organ in algae, fungi bryophytes, pteridophytes and gymnosperms.
Antibiotic	:	One of a group of organic compounds, varying in structure, that are produced by micro-organisms and can kill or inhibit the activities of other micro-organisms.
Ascogonium	:	The female gametangium of certain ascomycete.
Autogamy	:	Self fertilization.
Ascocarp	:	The fruiting body of ascomycete fungi.
Apothecium	:	Cup or disc shaped ascocarp.
Axopodium	:	A pseudopodium which contains straight, rigid axoneme is called axopodium.
Basidium	:	The cell of basidiomycete fungus that produces the haploid basidiospores.
Basidiocarp	:	Fruiting body of basidiomycetes.
Bacteriochlorophyll	:	A type of chlorophyll unique to photosynthetic bacteria.
Carotenoids	:	A group of pigments comprising carotenes and xanthophylls.
Carotene	:	This is orange pigment made up of hydrocarbons.
Cilia	:	They are identical structure of flagella, though shorter and usually aranged in groups. They are whip-like extension of certain cells that beat rapidly thereby causing locomotion.
Culture medium	:	A mixture of nutrients, which may be used in liquid form or solidified with agar, used to cultivate micro-organisms such as bacteria.
Cyclosis	:	The streaming type movement of cytoplasm.
Diatoms	:	They are soap box shaped and repdoduce asexually by fission producing successive smaller generations until size is restored through sexual reproduction by auxospores.
Dicots	:	Plants with two cotyledons in their seeds.
Endosperm	:	The nutritive tissue that surrounds embryo in angiosperms.
Epiphyte	:	Plants growing on other plants but do not take food and water from them.
Flagella	:	Eukaryotic flagella have 9 + 2 structure as that of cilia. They are longer than cilia but less numerous.
Fructification	:	Fruiting body.

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Fucoxanthin	:	An xanthophyll pigment of brown algae.
Gametophyte	:	Gamete producing haploid phase of a plant.
Hydrophytes	:	Plants found in aquatic conditions.
Heterospory	:	Existence of two types of spores *i.e.* microspores and megaspores.
Hypnospore	:	Under unfavourable conditions protoplasm may develop thick wall to form hypnospore in some green algae.
Laminarin	:	The chief food reserve of brown algae.
Monocots	:	Angiospermic plants with single cotyledon in their seeds.
Marine	:	Found in sea.
Mating types	:	Morphologically alike but physiologically different.
Nuclear dimorphism	:	A protist is said to exhibit nuclear dimorphism when it contains two morpholocially and functionally distinct nuclei *i.e.* small micronucleus and large macronucleus.
Orthotropous	:	Straight ovule found in gymnosperms and some angiosperms.
Perennial	:	Plants which grow for many seasons.
Pollination	:	Transference of pollen grains to stigma (in angiosperms).
Polyembryony	:	Formation of many embryos within single seed.
Pyrenoids	:	Starch storing proteinaceous bodies in some algae.
Phycocolloids	:	A covering of alginic acid on cellulosic cell walls of brown algae.
Protista	:	A kingdom of aquatic unicellular, eukaryotic microorganisms.
Pseudopodia	:	A temporary finger-like projection which helps in locomotion and feeding.
Rhizome	:	Underground, unbranched stem in ferns.
Syngamy	:	Act of fertilization.
Sporophyte	:	Spore producing diploid phase in a plant.
Siphonaceous	:	Multinuclear thallus but not divided into cells.
Sporogonium	:	Sporophyte in bryophytes usually differentiated into foot, seta and capsule.
Slime mould	:	They are multinucleate, lack cell walls, display amoeboid movements. However for spores with cellulose cell walls in sporangia.
Xerophytes	:	Plants growing in dry habitats.

NCERT FILE Solved

NCERT Exercise Questions

1. What is the basis of classification of algae ?

Ans. Criteria taken for classification of algae are :

(i) Pigments; **(ii)** Stored food; **(iii)** Nature of cell wall; **(vi)** Flagellar number and position of insertions and **(v)** Habitat.

2. When and where does reduction division take place of a liverwort, a moss, a fern, a gymnosperm and an angiosperm ?

Ans. Liverwort. In liverwort like *Marchantia*, meiosis occurs in spore mother cells of capsule in sporogonium. This leads to formation of haploid spores.

Moss. In moss like *Funaria*, meiosis takes place in spore mother cells of spore sacs in capsule of sporogonium.

Sporogonium is formed from diploid zygote formed after fusion of egg in archegonium and sperms.

Fern. Fern plant like *Dryopteris* bears fertile leaves **(sporophylls).** On sporophylls, sporangia are borne. Meiosis takes place in spore mother cells of sporangium to form haploid spores, which on germination give rise prothalli on which gametes are borne.

Gymnosperm. In gymnosperms like *Pinus*, meiosis takes place in microsporangia present on microsporophylls. Meiosis occurs in microspore mother cells to form haploid pollen grains. Pollen grains give rise to male gametopyte.

For the formation of megaspores (haploid) meiosis takes place in megaspore mother cell of ovule. Megaspore takes part in formation of female gametophyte.

Angiosperms. Pollen grains (haploid) are formed in microspore mother cells of pollen sacs in anther of stamen.

Pollen grain (microspore) leads to the formation of male gametophyte.

Inside ovary, ovules are borne. In nucellus of ovule, megaspore mother cell is present which undergoes meiosis to form haploid megaspores. Functional megaspore forms embryo sac (female gametophyte).

3. Name three groups of plants that bear archegonia. Briefly describe the life cycle of any one of them.

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Ans. **(a)** Groups of plants bearing archegonia. **(i)** Bryophyta **(ii)** Pteridophyta **(iii)** Gymnosperm

(b) Describe the life cycle of *Funaria* (moss). *Dryopteris* (Fern) or *Pinus* (as given in Chapter 3).

4. Mention the ploidy in the following : Protonemal cell of a moss, Primary endosperm nucleus in dicot, Leaf cell of a moss, Prothallus cell of a fern, Gemma cell in *Marchantia*, Meristem cell of monocot, Ovum of a liverwort and Zygote of a fern.

Ans.
- **(i)** Protonemal cell of a moss — Haploid
- **(ii)** Primary endosperm nucleus in a dicot — Triploid
- **(iii)** Leaf cell of a moss — Haploid
- **(iv)** Prothallus of fern — Haploid
- **(v)** Gemma cell in *Marchantia* — Haploid
- **(vi)** Meristem cell of monocot — Diploid
- **(vii)** Ovum of a liverwort — Haploid
- **(viii)** Zygote of a fern — Diploid

5. Write note on economic importance of algae and gymnosperms.

Ans. Refer chapter 3 for **economic importance of algae**, pages 11-12 and gymnosperms, page 32.

6. Both gymnosperms and angiosperms bear seeds, then why are they classified separately ?

Ans. Gymnosperms and Angiosperms have been classified separately due to following reasons :

(i) Gymnosperms bear naked seeds, but in angiosperms seeds are covered with fruit wall (pericarp).

(ii) Double fertilization is present in angiosperms, which is absent in gymnosperms.

(iii) Endosperm in angiosperms in triploid, which is haploid in gymnosperms.

7. What is heterospory ? Briefly comment on its significance. Give examples.

Ans. Genera like *Selaginella* and *Salvinia* in Pteridophytes bear two kinds of spores, **macro** (large) and **micro** (small) **spores** are called heterosporous. Microspores and megaspores germinate to give rise to male and female gametophytes respectively.

Significance. The female gametophytes in heterosporous plants are retained on the parent sporophytes for variable periods. The development of zygotes into young embryos occur in female gametophytes. This step is said to be precursor of **seed habit** in gymnosperms and angiosperms where all the members are heterosporous.

Examples. *Selaginella, Salvinia, Marsilea.*

8. Explain the following with suitable examples :

(i) Protonema; (ii) Antheridium; (iii) Archegonium; (iv) Diplontic; (v) Sporophyll; (vi) Isogamy.

Ans. **(i) Protonema.** It appears due to germination of spore in moss. It is the gametophytic stage which is creeping, green branched and filamentous. From this leafy stage of moss gametophyte appears.

e.g. Funaria.

(ii) Antheridium. It is multicellular, jacketed, male sex organ. Each antheridium which is usually round or club shaped is surrounded by jacket protecting the mass of androcytes. Androcytes or sperm mother cells form number of sperms or male gametes.

e.g. Marchantia, Funaria, Ferns.

(iii) Archegonium. Archegonium is female sex organ in bryophytes and pteridophytes and gymnosperms. It bears a tubular **neck** and swollen, lower **venter.**

Neck usually contains one or many neck canal cells. In venter egg (oosphere) and venter canal cell are present. *e.g. Marchantia, Funaria,* Ferns, *Pinus* etc.

(iv) Diplontic life cycle. Refer chapter-3, Plant life cycles and Alternation of generations, page 36-37.

(v) Sporophyll. Modified leaf bearing sporangia are called **sporophylls.** They may be of two types *i.e.* **microsporophylls** and **megasporophylls.** Microsporophylls bear microsporangia and megasporophylls bear megasporangia. They may get clustered to form male cones and female cones respectively.

e.g. sporophyll – Ferns

Microsporophylls and Megasporophylls – *Pinus.*

(vi) Isogamy. It is the fusion of gametes, where both the fusing gametes are morphologically and physiologically identical.

e.g. Chlamydomonas.

9. Differentiate between the following :

(i) Red algae and brown algae

(ii) Liverworts and moss

(iii) Homosporous and heterosporous pteridophyte

(iv) Syngamy and triple fusion.

Ans. **(i) Red algae and brown algae**

Refer table 9, page 12.

(ii) Liverworts and moss

Refer table 13, page 20.

(iii) Homosporous and heterosporous pteridophyte

Refer table 13, page 26.

(iv) Syngamy and triple fusion

Refer table 15, page 35.

10. How would you distinguish monocots from dicots ?

Ans. Refer Table 11 of Chapter 2.

11. Match the following (Column I with Column II) :

Ans.

	Column I		Column II
A.	*Chlamydomonas*	**(i)**	Moss
B.	*Cycas*	**(ii)**	Pteridophyte
C.	*Selaginella*	**(iii)**	Algae
D.	*Sphagnum*	**(iv)**	Gymnosperm

Ans. **A.** (*iii*); **B.** (*iv*); **C.** (*ii*); **D.** (*i*)

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NCERT Exemplar Problems

A. MULTIPLE CHOICE QUESTIONS

1. Cyanobacteria are classified under :
   (a) Protista (b) Plantae
   (c) Monera (d) Algae
2. Fusion of two gametes which are dissimilar in size is termed as :
   (a) Oogamy (b) Isogamy
   (c) Anisogamy (d) Zoogamy
3. Holdfast, stipe and frond constitutes the plant body in case of :
   (a) Rhodophyceae (b) Chlorophyceae
   (c) Phaeophyceae (d) All of the above
4. A plant shows thallus level of organization. It shows rhizoids and is haploid. It needs water to complete its life cycle because the male gametes are motile. Identify the group to which it belongs to :
   (a) Pteridophytes (b) Gymnosperms
   (c) Monocots (d) Bryophytes
5. A prothallus is :
   (a) A structure in pteridophytes formed before the thallus develops
   (b) A sporophytic free living structure formed in pteridophytes
   (c) A gametophyte free living structure formed in pteridophytes
   (d) A primitive structure formed after fertilization in pteridophytes
6. Plants of this group are diploid and well adapted to extreme conditions. They grow bearing sporophylls in compact structures called cones. The group in reference is :
   (a) Monocots (b) Dicots
   (c) Pteridophytes (d) Gymnosperms
7. The embryo sac of an Angiosperm is made up of :
   (a) 8 cells (b) 7 cells and 8 nuclei
   (c) 8 nuclei (d) 7 cells and 7 nuclei
8. If the diploid number of a flowering plant is 36. What would be the chromosome number in its endosperm :
   (a) 36 (b) 18
   (c) 54 (d) 72
9. Protonema is :
   (a) Haploid and is found in mosses
   (b) Diploid and is found in liverworts
   (c) Diploid and is found in pteridophytes
   (d) Haploid and is found in pteridophytes
10. The giant Redwood tree (*Sequoia sempervirens*) is a/an :
    (a) Angiosperm (b) Free fern
    (c) Pteridophyte (d) Gymnosperm

ANSWERS

1. (a); **2.** (c); **3.** (c); **4.** (d); **5.** (c); **6.** (b); **7.** (b); **8.** (c); **9.** (a); **10.** (c);

B. VERY SHORT ANSWER TYPE QUESTIONS

1. **Food is stored as floridean starch in Rhodophyceae. Mannitol is a reserve food material in which group of algae ?**

Ans. Phaeophyceae

2. **Give an example of plants with :**
   (a) Haplontic life cycle
   (b) Diplontic life cycle
   (c) Haplo-diplontic life cycle

Ans. **Haplontic life cycle :** Examples – *Ulothrix*, *Spirogyra*
Diplontic life cycle : Examples – Gymnosperms (*Pinus*, *Cycas*) and Angiosperms (Potato, Tomato).
Haplo-diplontic life cycle : Bryophytes (*Marchantia*, *Funaria*)

3. **The plant body in higher plants is well differentiated and well developed. Roots are the organs used for the absorption. What is equivalent of roots in the less developed lower plants ?**

Ans. **Algae** may bear **holdfast** or **hapteron** which performs only the function of fixation.
Fungi may show the presence of haustoria.
Bryophytes show rhizoids as fixing and absorbing organs.

4. **Most algal genera show haplontic life cycle. Name an alga which is :**
   (a) Haplo-diplontic (b) Diplontic

Ans. *Ectocarpus* is haplo-diplontic.
Fucus is diplontic.

5. **In bryophytes male and female sex organs are called ..... and ..... .**

Ans. In bryophytes male and female sex organs are called **antheridium** and **archegonium**.

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C. SHORT ANSWER TYPE QUESTIONS

1. Why bryophytes are called the amphibians of plant kingdom ?

Ans. Bryophytes grow on soil (terrestrial) but need water for activities like swimming of motile sperms, dehiscence of antheridia etc. That is why they are usually found at shady moist places and are called as amphibians of plant kingdom.

2. The male and female reproductive organs of several pteridophytes and gymnosperms are comparable to floral structures of angiosperms. Make an attempt to compare the various reproductive parts of pteridophytes and gymnosperms with reproductive structures of angiosperms.

Ans.

Character	Pteridophyte	Gymnosperm	Angiosperm
1. **Sex organ**	Cone, strobilus, sporophyll	Cone	Flower
2. **Male sex organ**	Microsporophyll	Microsporophyll	Stamen
3. **Female sex organ**	Megasporophyll	Megasporophyll	Carpel
4. **Megaspore containing structure**	Megasporangium	Megasporangium	Ovule
5. **Microspore containing structure**	Microsporangium	Microsporangium	Pollen sacs in anther
6. **Male spore**	Microspore	Microspore	Pollen grain
7. **Egg containing structure**	Megaspore	Megaspore	Embryo sac

3. Heterospory i.e., formation of two types of spores – microspores and megaspores is a characteristic feature in the life cycle of a few members of pteridophytes and all spermatophytes. Do you think heterospory has some evolutionary significance in plant kingdom ?

Ans. Due to formation of two types of spores, following modifications in life cycle occur :

(i) Reduction in gametophytic phase

(ii) *In situ* germination of spores

(iii) Retention of megagametophyte in megasporangium.

Heterospory helps in highly developed seed formation thus having evolutionary significance.

4. How far does *Selaginella* are of the few living members of lycopodiales (pteridophytes) fall short of seed habit ?

Ans. *Selaginella* is a heterosporous pteridophyte but still fails to form seeds. For details refer text.

5. Each plant or group of plants has some phylogenetic significance in relation to evolution : *Cycas,* one of the few living members of gymnosperms is called as the 'relic of past'. Can you establish a phylogenetic relationship of *Cycas* with any other group of plants that justifies the above statement ?

Ans. *Cycas* is called "relic of past" due to following reasons:

(i) Growth is slow.

(ii) Megasporophylls not compact.

(iii) Motile sperms (flagellated)

(iv) Circinate ptyxis (fern like)

(v) Persistent leaf bases

(vi) Monoxylic wood.

6. The heterosporous pteridophytes show certain characteristics which are precursor to the seed habit in gymnosperms. Explain.

Ans. Heterospory is present in *Selaginella* (a pteridophyte). Microspores produce male gametophytes and megaspores produce female gametophytes–Male gametophyte leads to formation of male gametes. Female gametophyte forms archegonia in which female gamete egg is present. It also provides food to the developing embryo.

Thus it finally leads to reduction of gametophyte, *in situ* germination of seeds and retention of female gametophyte in megasporangium, thereby taking part in seed formation in gymnosperms.

7. Comment on life cycle and nature of fern prothallus.

Ans. Refer **'Pteridophyta'** of this chapter.

8. How are the male and female gametophytes of pteridophytes and gymnosperms different from each other ?

Ans. In **pteridophytes** male gametophyte in plants like *Selaginella* in endoscopic and bears antheridia. Female gametophyte bears archegonia.

In **gymnosperms**, male gametophyte is highly reduce and made up of limited cells equivalent to pollen grain. Female gametophyte, here is multicellular and contains archegonia. It is retained within megasporangium.

9. In which plant you look for mycorrhiza and coralloid roots ? Also explain what these terms means.

Ans. *Mycorrhiza* is the association of roots and fungi. They show the symbiotic phenomenon e.g. *Pinus, Abies, Cedrus,* **Coralloid roots** exhibit the association of blue green algae and dichotomously branched roots in *Cycas.* The blue green algae like *Nostoc* are capable of nitrogen fixation.

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D. LONG ANSWER TYPE QUESTIONS

1. Gametophyte is a dominant phase in life cycle of a bryophyte. Explain.

Ans. Plant body in Bryophytes is gametophyte. In liverworts, it is thallus like and in mosses it is leafy. On this plant body male sex organs (antheridia) and female sex organs (archegonia) are borne. Flagellated sperms (male gametes) are released from antheridia and female gamete (egg) is present in archegonium. After fertilization zygote (2n) sporophytic stage starts. It leads to the formation of sporogonium (2n) in which haploid spores are formed.

2. With the help of schematic diagram, describe the haplo-diplontic life cycle pattern of a plant group.

Ans. Refer **'Haplo-diplontic life cycle' of 'Plant life cycles'** in this chapter.

3. Lichen is usually cited as an example of 'symbiosis' in plants where an algal and a fungal species live together for their mutual benefit. Which of the following will happen if algal and fungal partners are separated from each other?

(a) Both will survive and grow normally and independent from each other.

(b) Both will die

(c) Algal component will survive while the fungal component will die.

(d) Fungal component will survive while algal partner will die.

Based on your answer how do you justify this association as symbiosis.

Ans. (b) Both algae and fungal species will die. The fungus provides protection, holds water and provides place to live to algal partner. Algae is autotrophic and carries N_2 fixation (e.g. *Nostoc*). Due to this phenomenon of symbiosis, lichen can grow on barren rock etc. Algae or fungi alone cannot survive on such conditions.

4. Explain why sexual reproduction in angiosperms is said to take place through double fertilization and triple fusion. Also draw a labelled diagram of embryo sac to explain the phenomena.

Ans. Two male gametes are discharged into embryo sac of ovule. One male gamete fuses with egg to form zygote (2n). Second male gamete fuses with diploid secondary nucleus to form primary endosperm nucleus (3n). Because both male gametes are involved, the process is called double fertilization. Zygote forms embryo (2n) and primary endosperm nucleus forms endosperm (3n).

Refer Fig. 42 of this chapter.

5. Draw labelled diagrams of :

(a) Female and male thallus of a liverwort.

(b) Gametophyte and sporophyte of *Funaria*.

(c) Alternation of generation in Angiosperm.

Ans. (a) Refer Fig. 16 of this chapter.

(b) Refer Fig. 17 – Fig. 20 of this chapter.

(c) Refer Fig. 45 of this chapter.

HOTS Higher Order Thinking Skills & Brain Twisting

QUESTIONS WITH ANSWERS

Very Short Answer Questions *One mark each*

1. What are dimorphic leaves?

Ans. Presence of two types of leaves i.e. foliage and scale leaves e.g. *Pinus*.

2. Define circinate ptyxis.

Ans. It is coiling of young growing leaves like spring of a watch where growing apex is protected.

3. What is sporophyll?

Ans. Sporangia bearing leaves.

4. Name a plant which is called living fossil.

Ans. *Ginkgo biloba*

5. Name the female gametophyte in angiosperms.

Ans. Embryo sac.

6. What is peat?

Ans. Peat is a dark brown, semi-decomposed and semi-fossilised matter found in acidic marshes.

7. What is hypnospore?

Ans. It is thick walled non-motile resting spore meant for perennation and multiplication in green algae.

8. Define siphonogamy.

Ans. It is fertilization brought out with the help of pollen tube.

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9. What is endosperm?

Ans. It is full of food and provides nourishment to developing embryo in ovule.

10. What is frond?

Ans. Large sized, compound leaves of ferns are called as fronds.

11. Which type of ovules are present in gymnosperms?

Ans. Orthotropous, unitegmic and sessile.

12. Which green alga is used by space travellers as protein rich food?

Ans. *Chlorella*

13. Name the algae where food is stored in the form of laminarian.

Ans. Brown algae (Phaeophyceae)

Short Answer Questions *Two marks each*

1. Give one example each of Chlorophyceae, Phaeophyceae and Rhodophyceae.

Ans. Chlorophyceae: *Ulothrix;* **Phaeophyceae :** *Sargassum;* **Rhodophyceae :** *Batrachospernum.*

2. Why vascular plants dominate the land?

Ans. (i) Presence of mechanical tissue;

(ii) Presence of roots for anchoring and absorption of water and minerals;

(iii) Covering of aerial parts with cutin.

3. Name the pigments present in brown algae.

Ans. Chlorophyll-a, d and β, α carotenes and xanthophylls.

4. Name the pigments present in red algae.

Ans. Chlorophyll-a, d and α, β carotenes, xanthophylls and biliproteins.

5. Name some algae which are used as food.

Ans. *Chlorella, Ulva, Caulerpa*

6. Why mosses are considered ecologically important?

Ans. Mosses along with lichens are first to colonise rocks.

7. Which event has been considered important in pteridophyte for evolution of seed habit?

Ans. Development of zygote into young embryo takes place within the female gametophyte.

8. What is numerical taxonomy?

Ans. It is the quantitative assessment of characters in organisms. The relationship of organisms is numerically determined usually with the help of computer.

Short Answer Questions *Three marks each*

1. Write the economic importance of gymnosperms.
2. Discuss some salient features of dicotyledons.
3. Write about formation of primary endosperm nucleus.
4. What is double fertilization?
5. What is the advantage of development of seed habit in seed plants.
6. How bryophytes differ from pteridophytes.
7. Describe some distinguishing features of mosses.

Long Answer Questions *Five marks each*

1. Distinguish between gymnosperms and angiosperms.
2. Why *Ginkgo biloba* is called living fossil?
3. How natural system of classification differs from artificial system of classification.
4. Differentiate between antheridia and archegonia.
5. Discuss the haplontic and diplontic types of life cycles.
6. Write briefly about sporophyte of bryophytes.

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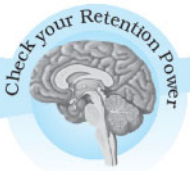

QUICK MEMORY TEST

A. Say True or False

Write "True" or "False".

1. Ferns are mostly found in dry climate.
2. True indusium is present in *Pteris*.
3. Group of sporangia is called sorus.
4. In protostele there is no pith in the centre.
5. The leaves of ferns are microphyllous.
6. The sori bearing leaves of ferns are called sporophylls.
7. The stele of *Dryopteris* is dictyostele.
8. The fern is heterosporous.
9. Megaspore on germination produces female gametophyte.
10. In *Selaginella* gametophyte is dominant generation.
11. In *Selaginella* sperms are multiflagellated.
12. Rhizophore of *Selaginella* is 'organ suigeneris'.
13. In precocious germination, the spore germinates while still in the sporangium.
14. Formation of gametophyte from sporophyte without production of spores is called apospory.
15. Biciliate antherozoids are found in ferns.
16. In ferns there is self fertilization.

B. Complete the missing links

1. Fill the following sentences with the suitable word :

(a) The yellow or brown spots which have sporangia in ferns are called .....

(b) Cones represent the ..... organs in the gymnosperms.

(c) The gymnosperms are ..... seeded plants whereas angiosperms are .....

(d) The ..... are root like structures which help in anchorage and absorption of water in bryophytes.

2. Fill the following sentences with the suitable word :

(a) In algae sporophytic and gametophytic stages are.....

(b) In angiosperms ovary ripens into.....which contains the seeds.

(c) In pteridophytes branching is never.....

(d) Green algae are considered.....of all terrestrial plants.

(e) In red algae reserve food material is.....starch.

(f) Male gametes in red algae are called.....

(g) .....from red alga is used in the preparation of chocolate.

(h) Brown algae contains dominating pigment.....

(i) Pleurilocular sporangia in *Ectocarpus* contain..... which are formed without meiosis.

(j) .....a green alga causes a disease on tea.

(k) *Sphagnum* has absorptive power and.....properties.

(l) In *Funaria* spore germinates to give rise to.....

(m) Ferns contain underground stem called.....

C. Choose the correct alternative

1. In **anisogamy/oogamy**, the female gamete is bigger, passive, non-motile and laden with food.
2. In rhodophyceae there is predominance of pigment **r-phycoerythrin/phycocyanin.**
3. The **gametophyte/sporophyte** bear antheridia and archegonia.

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4. In pteridophyte plant **rhizoids/roots** are present.
5. Prothallus of fern in **haploid/diploid**.
6. Hypnospores are **thin walled/thick walled** resting spores.

Answers QUICK MEMORY TEST

A. Say True or False

1. False; **2.** False; **3.** True; **4.** True; **5.** False; **6.** True; **7.** True; **8.** False; **9.** True; **10.** False; **11.** False; **12.** True; **13.** True; **14.** True; **15.** False; **16.** False.

B. Complete the missing links

1. **(a)** sori; **(b)** sex; **(c)** naked, fruit bearing plants; **(d)** rhizoids.

2. **(a)** independent; **(b)** fruit; **(c)** axillary; **(d)** ancestors; **(e)** floridean; **(f)** spermatia; **(g)** Carragenin; **(h)** fucoxanthin; (i) zoospores; **(j)** *Cephaleuros*; **(k)** antiseptic; **(l)** protonema; **(m)** rhizome.

C. Choose the correct alternative

1. Oogamy; **2.** r-phycoerythrin; **3.** Gametophyte; **4.** Roots; **5.** Haploid; **6.** Thick walled.

REVISION EXERCISES

Very Short Answer Questions

One mark each

1. Name any red alga which is used as vegetable.
2. Which type of flagella are present in brown algae ?
3. Name the alga from which algin is prepared commercially.
4. Name any branched filamentous green alga.
5. In which alga, sexual reproduction takes place by conjugation ?
6. Name a plant, where rhizoids are multicellular, branched and obiquely septate.
7. In which bryophtyte, sprogonium is embedded in thallus ?
8. Name the filamentous structure which appears in mosses due to germination of spore.
9. What is the specific term for cluster of sporangia in *Dryopteris*?
10. Where the antheridia and archegonia are located in fern ?
11. Name the membranous covering protecting the sporangia in *Dryopteris.*
12. Why plant body of *Dryopteris* is called sporophyte ?
13. What are the hairy structures present on young leaves and petiole in a fern ?
14. How many generations are represented in *Pinus* seed ?
15. How many cotyledons are present in *Pinus* embryo ?
16. Give an example of a plant which produces seed but not fruit.
17. Name the smallest angiospermic plant.
18. What is the genetic constitution of endosperm in angiosperms ?
19. Read the following statements and select the correct statements from the given choices:
    (i) Methanogens are present in the guts of ruminant animals.
    (ii) Mycoplasma has distinct cell wall
    (iii) Viroids are infectious naked DNA molecules
    (iv) Algal component of lichen is phycobiont.
    (a) (ii) and (iii) **(b)** (i) and (iv) **(c)** (i) and (iii) **(d)** (ii) and (iv) ***(Kerala Board 2017)***

ANSWERS

1. *Porphyra*; **2.** Whiplash and tinsel type; **3.** *Laminaria*; **4.** *Cladophora*; **5.** *Spirogyra*; **6.** *Funaria*; **7.** *Riccia*; **8.** Protonema; **9.** Sori; **10.** Prothallus; **11.** Stomium; **12.** Because it represents spore producing diploid phase; **13.** Ramenta; **14.** Three; **15.** Many cotyledons; **16.** *Cycas*; **17.** *Wolffia*; **18.** Triploid; **19.** (b) (i) and (iv).

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Short Answer Questions

Two marks each

1. What do you understand by naked DNA ?
2. What is water bloom ?
3. What is mixotrophic mode of nutrition ?
4. Why the seed plants are most successful of all land plants ?
5. What is algin ?
6. What are coralloid roots ?
7. Name the largest unicellular alga.
8. What is polyembryony ?
9. How would you identify the gametophytic plant body of liverwort.
10. What is heterospory ?
11. Algae are useful to man in a variety of ways. Suggest any four uses of algae. ***(Kerala Board 2017)***

ANSWERS

1. DNA in which associated histones are absent and not surrounded by nuclear envelope.
2. Change in colour of water body due to excess growth of planktonic algae is called water bloom.
3. In mixotrophic mode of nutrition, get their food supply by more than one method at same or different times due to change in environment.
4. Seed plants are the most successful of all land plants because external supply of water is not required for fertilization.
5. It is a crystalline powder extracted from the outer cell walls of kelps (giant brown algae).
6. Coralloid roots are irregular negatively geotropic, dichotomously branched coral like root. Root hairs and root caps are absent on coralloid roots.
7. *Acetabularia*.
8. It is the formation of more than one embryo in same seed.
9. Liverwort like *Marchantia* bear thallus like structure on which sex organs are borne.
10. Production of two types of spores is called heterospory.
11. **Uses of Algae :**
    (i) **As food :** Algae like *Ulva*, *Spirogyra*, etc. are edible, *Chlorella* can be grown to provide human food rich in protein, lipid, carbohydrates, vitamins, and minerals.
    (ii) **As manure :** Calcium containing green algae like *Chara* is useful in acidic soils while some other varieties are useful in alkaline soils.
    (iii) **In sewage oxidation tanks :** Algae like *Chlamydomonas*, *Chlorella* are inoculated in sewage oxidation tanks to provide required oxygen to decompose fungi and bacteria.
    (iv) **Antibiotics :** *Chlorella* contains an antibiotic called 'chlorellin'.

Short Answer Questions

Three marks each

1. Distinguish between cryptogamae and phanerogamae.
2. Draw a sketch of unicellular non-flagellated member of algae.
3. List common modes of reproduction in algae.
4. How does algae differ from fungi ?
5. Name the different pigments found in algae.
6. Explain briefly alternation of generations in bryophytes.
7. Describe the main features of pteridophytes.
8. Name the four classes of pteridophytes.
9. Explain the nature of sporophylls in pteridophytes.
10. Describe the important characteristics of gymnosperms.

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Long Answer Questions

Five marks each

1. How are the delicate and soft fungal hyphae able to penetrate hard timbers ?
2. What characters of seed plants make them specially adapted to life on land ? ***(HOTS)***
3. Describe the similarities and differences in the sexual reproduction of moss and fern.
4. Compare the reproductive organs of gymnosperms and angiosperms with the help of diagrams.
5. List the events from pollination to fertilization in *Pinus*.
6. Draw diagrammatic representation of life cycle of *Dryopteris*. ***(HOTS)***
7. Describe the group characteristics and basic features of bryophytes. Define thallus, rhizoid and protonema.
8. Describe the structural organization of a fern sporophyte. Write the structural characteristics of gymnosperms. What are the identifying features of angiosperms?
9. Draw the diagrammatic life cycle of an angiosperm.
10. Give an account of double fertilization angiosperms. ***(Odisha 2012)***

COMPETITION FILE OBJECTIVE TYPE QUESTIONS

A. MULTIPLE CHOICE QUESTIONS (MCQs):

(From AIPMT & Other Competitive Examinations)

1. Yellow-green pigment is found in :
   (a) Xanthophyta (b) Chlorophyta (c) Phaeophyta (d) Rhodophyta ***(UP-CPMT 2009)***
2. Mannitol is the stored food in :
   (a) *Chara* (b) *Porphyra* (c) *Fucus* (d) *Gracillaria* ***(CBSE 2009)***
3. Which one of the following has haplontic life cycle ?
   (a) *Funaria* (b) *Polytrichum* (c) *Ustilago* (d) Wheat ***(CBSE 2009)***
4. Which one of the following plants is monoecious ?
   (a) *Marchantia* (b) *Pinus* (c) *Cycas* (d) Papaya ***(CBSE 2009)***
5. Which one is the wrong pairing for the disease and its causal organism ?
   (a) Late blight of potato—*Alternaria solani* (b) Black rust of wheat—*Puccinia graminis*
   (c) Loose smut of wheat—*Ustilago nuda* (d) Root-knot of vegetables—*Meloidogyne* sp. ***(CBSE 2009)***
6. Which one of the following is a vascular cryptogam ?
   (a) *Equisetum* (b) *Ginkgo* (c) *Marchantia* (d) *Cedrus* ***(CBSE 2009)***
7. Which one of the following is considered important in the development of seed habit ?
   (a) Dependent sporophyte (b) Heterospory
   (c) Haplontic life cycle (d) Free living gametophyte ***(CBSE 2009)***
8. The lichens represent symbiotic relationship between :
   (a) Algae and bacteria (b) Fungi and higher plants
   (c) Algae and fungi (d) Viruses and bacteria ***(AMU 2011)***
9. Which of the following are commonly known as imperfect fungi.
   (a) Ascomycetes (b) Basidiomycetes (c) Deuteromycetes (d) Phycomycetes ***(AMU 2011)***
10. Cell in some filamentous cyanobacteria, which is specialised for nitrogen fixation is called :
    (a) Heterocyst (b) Mesosome (c) Volutin (d) Phycobillisome ***(AMU 2011)***
11. A plant disease in which pathogen is seen as a cottony growth on the surface of the host is called :
    (a) Downy mildew (b) Powdry mildew (c) Smut (d) Rust ***(AMU 2011)***

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12. Red algae differ from green algae and brown algae in having :
(a) No chlorophyll *a* (b) No differentiated cells
(c) No flagellated stage in their life cycle (d) Haemoglobin within their cells **(*AMU 2011*)**

13. Protein rich alga is :
(a) *Protosiphon* (b) *Porophyridium* (c) *Gelidium* (d) *Spirulina* **(*AMU 2011*)**

14. Which of the following is an unicellular sac-fungus ?
(a) *Claviceps* (b) *Saccharomyces* (c) *Penicillium*
(d) *Neurospora* (e) *Aspergillus* **(*Kerala 2011*)**

15. Which of the following is not matched correctly :
(a) *Anabaena* – Cyanobacteria
(b) *Amoeba* – Protozoa
(c) *Gonyaulax* – Dinoflagellates
(d) Thermoacidophils – Archaebacteria
(e) *Albugo* – Chrysophytes **(*Kerala 2011*)**

16. Which one of the following is a characteristic feature of Chrysophytes ?
(a) They are parasitic forms which cause diseases in animals
(b) They have a protein rich layer called pellicle
(c) They have indestructible wall layer deposited with silica
(d) They are commonly called dinoflagellates
(e) They are saprophytic protista **(*Kerala 2011*)**

17. Which of the following does not belong to the kingdom Protista ?
(a) Chrysophytes (b) Euglenoids (c) Ascomycetes
(d) Dinoflagellates (e) Protozoans **(*Kerala 2011*)**

18. Find out the correct statement :
(a) In lichens, the algal component is called phycobiont and fungal component is known as mycobiont, which are heterotrophic and autotrophic respectively.
(b) Viroid contains RNA of low molecular weight and protein coat.
(c) A virus contains both RNA and DNA.
(d) Viruses are obligatory parasites.
(e) Viruses that infect plants have double stranded RNA **(*Kerala 2011*)**

19. Match column I with column II and select the correct option.

	Column I (Kingdom)		Column II (Class)
A	Morels	1	Deuteromycetes
B	Smut	2	Ascomycetes
C	Bread mould	3	Basidiomycetes
D	Imperfect fungi	4	Phycomycetes

(a) A – 3, B – 4, C – 1, D – 2
(b) A – 2, B – 3, C – 4, D – 1
(c) A – 4, B – 1, C – 2, D – 3
(d) A – 3, B – 4, C – 2, D – 1
(e) A – 2, B – 1, C – 4, D – 3 **(*Kerala 2011*)**

20. Select the correct match from the options given below :
(A) Phaeophyceae – Mannitol
(B) Rhodophyceae – Dictyota
(C) Chlorophyceae – Non-motile gametes
(D) Rhodophyceae – r-Phycoerythrin
(a) A, B and C (b) B, C and D (c) A and C
(d) C and D (e) A and D **(*Kerala 2011*)**

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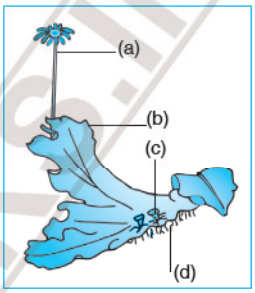
21. Which of the following Pteridophytes belong to class Pteropsida ?
(a) *Equisetum* and *Psilotum* (b) *Lycopodium* and *Adiantum*
(c) *Selaginella* and *Pteris* (d) *Pteris* and *Adiantum*
(e) *Dryopteris* and *Psilotum* **(*Kerala 2011*)**

22. *Selaginella* and *Salvinia* are considered to represent a significant step toward evolution of seed habit because :
(a) Megaspores possess endosperm and embryo surrounded by seed coat
(b) Embryo develops in female gametophyte which is retained on parent sporophyte
(c) Female gametophyte is free and gets dispersed like seeds
(d) Female gametophyte lacks archegonia **(*CBSE 2011*)**

23. Examine the figure given below and select the right option giving all the four parts (a, b, c, d) correctly identified

A	B	C	D
(a) Seta	Sporophyte	Protonema	Rhizoids
(b) Antheridiophore	Male thallus	Globule	Roots
(c) Archegoniophore	Female thallus	Gemmacup	Rhizoids
(d) Archegoniophore	Female thallus	Bud	Foot



(*CBSE 2011*)

24. Consider the following four statements whether they are correct or wrong ?
(A) The sporophyte in liverworts is more elaborate than that in mosses.
(B) *Salvinia* is heterosporous.
(C) The life-cycle in all seed bearing plants is diplontic.
(D) In *Pinus* male and female cones are borne on different trees.
The two *wrong* statements together are:
(a) Statements (B) and (C) (b) Statements (A) and (B)
(c) Statements (A) and (C) (d) Statements (A) and (D) **(*CBSE 2011*)**

25. The major pigments in rhodophyceae are:
(a) Chlorophyll *a* and *b* (b) Chlorophyll *a*, *c* and fucoxanthin
(c) Chlorophyll *a*, *d* and phycoerytherin (d) None of the above. **(*AMU 2012*)**

26. The largest antherozoids are found in:
(a) *Cycas* (b) *Cedrus* (c) *Ephedra* (d) *Pinus* **(*BHU 2012*)**

27. Bryophytes are called amphibians of plant kingdom because:
(a) They need a layer of water for reproduction (b) They are found in mostly aquatic condition
(c) They have vascular tissues (d) All of these. **(*BHU 2012*)**

28. Read the following five statements (A – E) and answer as asked next to them:
(A) In *Equisetum*, the female gametophyte is retained on the parent sporophyte
(B) In *Ginkgo*, male gametophyte is not independent
(C) The sporophyte in *Riccia* is more developed than that in *Polytrichum*
(D) Sexual reproduction in *Volvox* is isogamous
(E) The spores of slime moulds lack cell walls
How many of the above statements are correct?
(a) Two (b) Three (c) Four (d) One **(*AI PMT 2012*)**

29. Which one of the following pairs is wrongly matched?
(a) *Ginkgo* – Archegonia (b) *Salvinia* – Prothallus (c) Viroids – RNA (d) Mustard – Synergids
(*AI PMT 2012*)

30. In the five kingdom classification, *Chlamydomonas* and *Chlorella* have been included in:
(a) Protista (b) Algae (c) Plantae (d) Monera **(*AI PMT 2012*)**

31. The heterosporous pteridophyte belonging to the class Lycopsida is:
(a) *Selaginella* (b) *Psilotum* (c) *Equisetum*
(d) *Pteris* (e) *Adiantum* **(*Kerala 2012*)**

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32. Consider the following statements with respect to algae:
(A) Fusion between one large, non-motile female gamete and a smaller, motile male gamete is termed as oogamous
(B) Fusion of two gametes dissimilar in size is termed as isogamous
(C) Fusion of two gametes similar in size is called anisogamous
(D) In chlorophyceae the major pigments are chlorophyll *a* and *b*, and the food is stored as starch
(E) In rhodophyceae the major pigments are chlorophyll *a* and *d*, and the food is stored as mannitol
Of the above statements
(a) A and E alone are correct (b) C and E alone are correct
(c) A and B alone are correct (d) A and D alone are correct
(e) B and D alone are correct **(*Kerala 2012*)**

33. Consider the following statements with respect to gymnosperms and angiosperms:
(A) Double fertilization is an event unique to gymnosperms
(B) Angiosperms range in size from microscopic *Wolffia* to tall trees of *Sequoia*.
(C) In gymnosperms the seeds are not covered.
(D) In gymnosperms the male and female gametophytes have an independent free living existence.
Of the above statements
(a) A and B alone are correct (b) C alone is correct (c) B and C alone are correct
(d) C and D alone are correct (e) D alone is correct **(*Kerala 2012*)**

34. Choose the correct order of colours with respect to pigments, chlorophyll, phycoerythrin and fucoxanthin:
(a) Green, red and brown (b) Brown, green and red (c) Red, green and brown
(d) Green, brown and red (e) Brown, red and green **(*Kerala 2012*)**

35. Which of the following are the characters of dinoflagellates?
(A) Plankton *c* golden yellow algae with soap box like structure.
(B) Marine red biflagellated protista.
(C) Appear yellow, green, brown, blue and red in colour.
(D) Biflagellated organisms with pellicle.
(E) Saprophytic (or) parasitic unicellular forms
(a) A, B and C only (b) B, D and E only (c) B and C only
(d) B and E only (e) C, D and E only **(*Kerala 2012*)**

36. The green alga rich in proteins used as food supplements even by space travellers is:
(a) *Chlamydomonas* (b) *Volvox* (c) *Spirogyra*
(d) *Spirulina* (e) *Chlorella* **(*Kerala 2012*)**

37. Consider the following statements with respect to characteristic features of the kingdom.
(A) In Animalia the mode of nutrition is autotrophic. (B) In Monera the nuclear membrane is present.
(C) In Protista the cell type is prokaryotic. (D) In Plantae the cell wall is present.
Of the above statements
(a) A alone is correct (b) B alone is correct (c) C alone is correct
(d) D alone is correct (e) A, B and C are correct. **(*Kerala 2012*)**

38. Isogamous condition with non-flagellated gametes is found in :
(a) *Spirogyra* (b) *Volvox* (c) *Fucus*
(d) *Chlamydomonas* **(*NEET 2013*)**

39. Monoecious plant of *Chara* shows occurrence of :
(a) stamen and carpel of the same plant
(b) upper antheridium and lower oogonium on the same plant
(c) upper oogonium and lower antheridium on the same plant
(d) antheridiophore and archegoniophore on the same plant **(*NEET 2013*)**

40. Read the following statements (A-E) and answer the question which follows them.
(A) In liveworts, mosses, and ferns gametophytes are free-living
(B) Gymnosperms and some ferns are heterosperms and some ferns are heterosporous
(C) Sexual reproduction in *Fucus*, *Volvox* and *Albugo* is oogamous
(D) The sporophyte in liverworts is more elaborate than that in mosses

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(E) Both, Pinus and Marchantia are dioecious

How many of the above statements are correct ?

(a) Two (b) Three (c) Four (d) One ***(NEET 2013)***

41. Which of the following are likely to be present in deep sea water ?

(a) Eubacteria (b) Blue-green algae (c) Saprophytic fungi (d) Archaebacteria ***(NEET 2013)***

42. Meiosis takes place in :

(a) Conidia (b) Gemmule (c) Megaspore (d) Meiocyte ***(NEET 2013)***

43. The following plant placed under dicots but lacks cotyledons is :

(a) Maize (b) *Cuscuta* (c) Mustard (d) Linseed ***(NEET 2013)***

44. Which of the following is wrong about *Chara* ?

(a) Upper oogonium and lower round antheridium (b) Globule and nucule present on the same plant

(c) Upper antheridium and lower oogonium (d) Globule is male reproductive structure ***(AIPMT 2014)***

45. Anoxygenic photosynthesis is characteristics of

(a) *Rhodospirillium* (b)*Spirogyra* (c) *Chlamydomonas* (d) *Ulva* ***(AIPMT 2014)***

46. In which one of the following processes CO_2 is not released ?

(a) Aerobic respiration in plants (b) Aerobic respiration in animals

(c) Alcoholic fermentation (d) Lactate fermentation ***(AIPMT 2014)***

47. Which of the following is responsible for peat formation ?

(a) *Marchantia* (b) *Riccia* (c) *Funaria* (d) *Sphagnum.* ***(AIPMT 2014)***

48. Which one of the following shows isogamy with non-flagellated gametes ?

(a) *Sargassum* (b) *Ectocarpus* (c) *Ulothrix* (d) *Spirogyra.* ***(AIPMT 2014)***

49. Which one of the following living organisms completely lacks a cell wall ?

(a) Cyanobacteria (b) Sea-fan (*Gorgonia*) (c) *Saccharomyces* (d) Blue-green algae. ***(AIPMT 2014)***

50. Which one of the following fungi contains hallucinogens ?

(a) *Morchella esculenta* (b) *Amanita muscaria* (c) *Neurospora* sp. (d) *Ustilago* sp. ***(AIPMT 2014)***

51. Male gametophyte with least number of cells is present in :

(a) *Pteris* (b) *Funaria* (c) *Lilium* (d) *Pinus* ***(AIPMT 2014)***

52. An alga which can be employed as food for human being is :

(a) *Ulothrix* (b) *Chlorella* (c) *Spirogyra* (d) *Polysiphonia.* ***(AIPMT 2014)***

53. In angiosperms, during development of embryo, the suspensor cells develop from:

(a) Oospore (b) Integument

(c) Endosperm (d) Cotyledon ***(Maharashtra CET 2015)***

54. The gymnospermic endosperm differs from an angiospermic endosperm because in gymnosperms it is:

(a) Haploid and developed from female gametophyte

(b) Diploid and developed from female gametophyte

(c) Triploid and developed after fertilisation

(d) Triploid and developed before fertilisation ***(Maharashtra CET 2015)***

55. Which is not a Bryophyte?

(a) Hepaticopsida (b) Anthoceropsida

(c) Bryopsida (d) Lycopsida ***(Bihar CECE 2015)***

56. This provides brown colour to the algae.

(a) Chlorophyll *a* (b) Phycocyanin

(c) Fucoxanthin (d) Chlorophyll *b* ***(Bihar CECE 2015)***

57. Which one is a red algae?

(a) *Gelidium* (b) *Chlorella* (c) *Volvox* (d) *Ulothrix* ***(Bihar CECE 2015)***

58. Male gametophyte in angiosperms produces:

(a) Single sperm and two vegetative cells (b) Three sperms

(c) Two sperms and a vegetative cell (d) Single sperm and a vegetative cell ***(AIPMT 2015)***

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59. Which one is wrong statement?
(a) Haploid endosperm is typical feature of Gymnosperms.
(b) Brown algae have chlorophyll *a* and *c* and fucoxanthin.
(c) Archegonia are found in Bryophyte, Pteridophyte and Gymnosperms.
(d) *Mucor* has biflagellate zoospore. ***(AIPMT 2015)***

60. Microtubules are the constituents of :
(a) Cilia, flagella and peroxisomes (b) Spindle fibres, centrioles and cilia
(c) Centrioles, spindle fibres and chromatin (d) Centrosome, nucleosome and centrioles ***(NEET-I 2016)***

61. In bryophytes and pteridophytes, transport of medium gametes requires:
(a) Wind (b) Birds (c) Insects (d) Water ***(NEET-I 2016)***

62. Chrysophytes, Euglenoids, Dinoflagellates and Slime moulds are included in Kingdom:
(a) Monera (b) Protista (c) Fungi (d) Animalia ***(NEET-II 2016)***

63. Mycorrhiza is the example of :
(a) Amensalism (b) Antibiosis (c) Mutualism (d) Fungistasis ***(NEET-2017)***

64. Select the mismatch:
(a) *Cycas* – Dioecious
(b) *Salvinia* – Heterosporous
(c) *Equisetum* – Homosporous
(d) *Pinus* – Dioecious ***(NEET-2017)***

65. Which of the following is correctly matched for the product produced by them?
(a) *Methanobacterium* – Lactic acid
(b) *Penicillium notatum* – Acetic acid
(c) *Saccharomyces cerevisiae* – Ethanol
(d) *Acetobacter aceti* – Antibiotics ***(NEET-2017)***

66. Which among the following are the smallest living cells, known without a definite cell wall, pathogenic to plants as well as animals and can survive without oxygen?
(a) *Pseudomonas* (b) *Mycoplasma* (c) *Nostoc* (d) *Bacillus* ***(NEET-2017)***

67. An example of colonial alga is:
(a) *Volvox* (b) *Ulothrix* (c) *Spirogyra* (d) *Chlorella* ***(NEET-2017)***

68. Life cycles of *Ectocarpus* and *Fucus* respectively are:
(a) Diplontic, haplodiplontic (b) Haplodiplontic, diplontic
(c) Haplodiplontic, haplontic (d) Haplontic, diplontic ***(NEET-2017)***

69. After karyogamy followed by meiosis, spores are produced exogenously in:
(a) *Alternaria* (b) *Agaricus* (c) *Neurospora* (d) *Saccharomyces* ***(NEET-2018)***

70. Which one is ***wrongly*** matched?
(a) Biflagellate zoospores – *Brown algae* (b) Gemma cups – *Marchantia*
(c) Uniflagellate gametes – *Polysiphonia* (d) Unicellular organism – *Chlorella* ***(NEET-2018)***

71. Which of the following organisms are known as chief producers in the oceans?
(a) Diatoms (b) Cyanobacteria (c) Dinoflagellates (d) Euglenoids ***(NEET-2018)***

72. Which of the following statements is ***correct***?
(a) *Selaginella* is heterosporous, while *Salvinia* is homosporous.
(b) Horsetails are gymnosperms.
(c) Ovules are not enclosed by ovary wall in gymnosperms
(d) Stems are usually unbranched in both *Cycas* and *Cedrus*. ***(NEET-2018)***

73. Select the ***wrong*** statement:
(a) Mushrooms belong to Basidiomycetes.
(b) Pseudopodia are locomotory and feeding structures in Sporozoans.
(c) Cell wall is present in members of Fungi and Plantae
(d) Mitochondria are the powerhouse of the cell in all kingdoms except Monera. ***(NEET-2018)***

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74. Winged pollen grains are present in :

(a) *Cycas* (b) Mango (c) Mustard (d) *Pinus* ***(NEET-2018)***

ANSWERS

1. (a);	**2.** (a);	**3.** (c);	**4.** (b);	**5.** (a);	**6.** (a);	**7.** (b);	**8.** (c);	**9.** (c);	**10.** (a);
11. (b);	**12.** (c);	**13.** (d);	**14.** (b);	**15.** (e);	**16.** (c);	**17.** (c);	**18.** (d);	**19.** (b);	**20.** (e);
21. (d);	**22.** (b);	**23.** (c);	**24.** (d);	**25.** (c);	**26.** (a);	**27.** (a);	**28.** (d);	**29.** (b);	**30.** (a);
31. (a);	**32.** (d);	**33.** (b);	**34.** (a);	**35.** (c);	**36.** (d);	**37.** (d);	**38.** (a);	**39.** (c);	**40.** (b);
41. (d);	**42.** (d);	**43.** (b);	**44.** (c);	**45.** (a);	**46.** (d);	**47.** (d);	**48.** (d);	**49.** (b);	**50.** (c);
51. (c);	**52.** (b);	**53.** (a);	**54.** (a);	**55.** (d);	**56.** (c);	**57.** (a);	**58.** (c);	**59.** (d);	**60.** (b);
61. (d);	**62.** (b);	**63.** (c);	**64.** (d);	**65.** (c);	**66.** (b);	**67.** (a);	**68.** (b);	**69.** (b);	**70.** (c);
71. (a);	**72.** (a);	**73.** (b);	**74.** (d).						

B. CBSE - PMT (MAIN EXAMINATION) QUESTIONS :

1. Find out the false (F) statement from the following :

(i) *Fucus* and *Sargassum* both shows heterothallic habit.
(ii) Auxospores are found in diatom.
(iii) Viruses are more abundant in marine habit.
(iv) All plant infecting bacteria are gram positive and rod shaped.
(v) Red algae occurs both in marine and fresh water.
(vi) *Marsilea, Salvinia, Azolla* are aquatic, eusporangiate and heterosporous.
(vii) All bacteria have single circular chromosome per cell.
(viii) All desmids are found in marine habitat but diatoms are found as phytoplankton large in deep lakes.
(ix) *Welwitschia* has reproductive structure in its juvenile stage.
(x) *Moss* shows diplobiontic life cycle. ***(CBSE 2005)***

Ans. **(i)** F; **(iii)** F; **(iv)** F; **(vi)** F; **(viii)** F; **(ix)** F; **(x)** F.

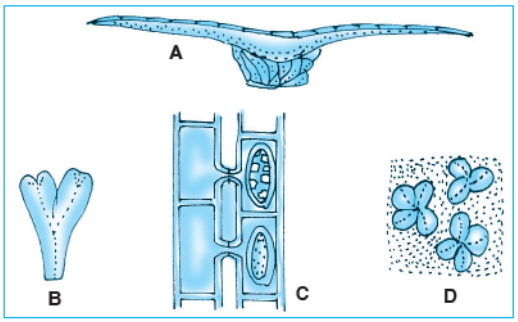
2. Match Column A with Column B :

Column A	Column B
1. Cup shaped chloroplast	**(i)** *Agaricus*
2. Ribbon shaped chloroplast	**(ii)** *Lichen*
3. Budding yeast	**(iii)** *Spirogyra*
4. White rust	**(iv)** *Zygonema*
5. Brown rust	**(v)** *Puccinia*
6. Smut	**(vi)** *Albugo*
7. Elaters	**(vii)** *Chlamydomonas*
8. Saprophytes	**(viii)** *Chara*
9. Globule nucleus	**(ix)** *Vaucheria*
10. Symbiotic	**(x)** *Ustilago*
	(xi) *Anthoceros*
	(xii) *Saccharomyces*
	(xiii) *Schizosaccharomyces*

(CBSE 2005)

Ans. **1.** (vii); **2.** (iii); **3.** (xii); **4** (vi); **5.** (v); **6.** (x); **7.** (xi); **8.** (i); **9.** (viii); **10.** (ii)

3. Identify the figures A to D. ***(CBSE 2006)***



Ans. **A.** V. S. *Marchantia* thallus;
B. *Riccia* thallus
C. *Spirogyra* showing scalariform conjugation with zygospores.
D. *Cycas* megasporangia.

4. Fill in the blanks :

Cycas, Pinus, Coralloid root, Vivipary, *Anabaena, Nostoc, Marsilea, Usnea, Oscillatoria*, Pneumatophore, *Eichhornia.* ***(CBSE 2007)***

(i) ..... is present in *Rhizophora.* It also shows ..... .
(ii) ..... is a gymnosperm and it has .....

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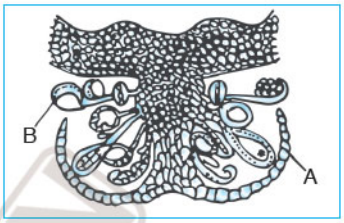
(iii) ..... is an aquatic pteridophyte and ..... is an aquatic angiosperm.

(iv) Heterocyst is found in ..... .

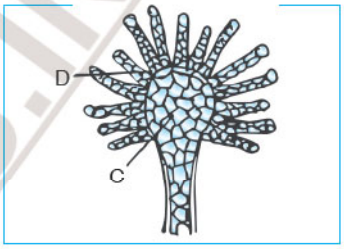
Ans. **(i)** Pneumatophore, Vivipary **(ii)** *Cycas*, Coralloid roots

(iii) *Marsilea*, *Eichhornia* **(iv)** *Nostoc*

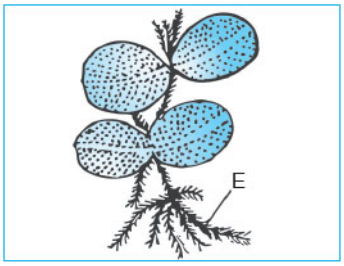
5. **(a)** Identify the given figure and label parts (A) and (B)



(b) Identify the given diagram and label parts (C) and (D)



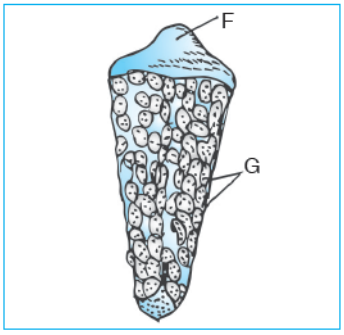
(c) Identify the given diagram and label parts (E)



(d) (i) In the given diagram write the condition of flower on the basis of position of ovary

(ii) Out of the following given examples write the most suitable examples for such flower (Cariander, Cucumber, Pear, Apple)

(e) Identify the shown part and name the organism and lable (F) and (G). **(*CBSE 2008*)**



Ans. **(a)** Figure given above is V.T.S of *Dryopteris* leaflet passing through a sorus. The part labelled as 'A' is true indusium and 'B' is sporangium.

(b) Figure shows conidiophore of *Aspergillus*, which is also called *Eurotium*. The parts labelled as (C) and (D) are known as **vesicle** and **primary sterigmata** or **phialides** respectively.

(c) Figure shows a type of free-floating hydrophytes called *Salvinia* and the labelled part 'E' is submerged leaf.

(d) (i) Figure shows **epigynous condition** of flower. In this, ovary or gynaecium is said to be inferior while other floral organs are called superior, *e.g.* : apple, sunflower, guava and cucumber.

(ii) Refer Ans. above (i).

(e) Figure shows the ventral view of microsporophyll of *Cycas* and the labelled part 'F' and 'G' are **apophysis** and **sori** respectively.

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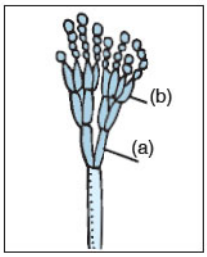
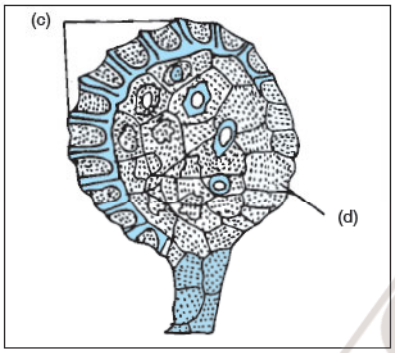
6. (i) Identify the given diagram and label (a) or (b) :



(ii) Identify the given diagram and label (c) or (d) :



(*CBSE 2009*)

Ans. **(i)** Conidiophore of *Penicillium*

(a) Ramus; **(b)** Phialides

(ii) Sporangium of fern

(c) Annulus **(d)** Stomium (*CBSE 2009*)

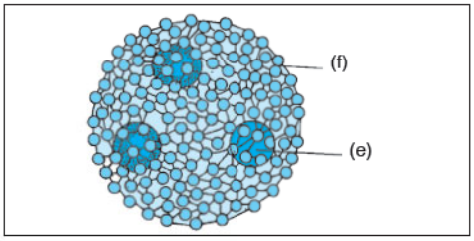
7. Match the contents of Column I with Column II :

Column I	Column II
(a) *Usnea*	(i) Zoospore
(b) *Mucor*	(ii) Zygospore
(c) *Zea mays*	(iii) Velamen
(d) *Equisetum*	(iv) Naked seed
(e) *Ginkgo biloba*	(v) Mutualism
	(vi) Predation
	(vii) Living fossil
	(viii) GM crop
	(ix) Rust
	(x) Horse tail
	(xi) Urediniospore
	(xii) Mycobiont
	(xiii) Club moss
	(xiv) Runner
	(xv) Indehiscent fruit
	(xvi) Scutellum

(*CBSE 2009*)

Ans. **(a)** v **(b)** ii **(c)** xv, xvi **(d)** x **(e)** iv, vii

8. Identify the given diagram and label (e) or (f) :



Ans. (e) Parent colony (f) Daughter colony (*CBSE 2009*)

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9. Fill in the blanks with the help of the following given words :

[Extinct, North-western, Tropical, *Fig*, *Ficus*, *Glomus*, Northern, Southern, *Pinus*, Diversity, *Ustilago*, Rust, Smut, *Staphylococcus*, Flemming, *Azospirillum*, Pasteur, *Selaginella*, *Chara*]

(a) In ..... (1) ..... areas ..... (2) ..... acts as keystone species.

(b) The species those are ..... (3) ..... in ..... (4) ..... parts of India are due to Jhoom cultivation.

(c) Loose ..... (5) ..... in wheat is caused by ..... (6) .....

(d) ..... (7) ..... could not grow on *Penicillium* containing culture, it was first observed by ..... (8)

(e) Beside *Polytrichum* and ..... (9) ..... female sex organ archegonia are also present in ..... (10) .....

(CBSE 2009)

Ans. (1) Tropical, (2) Fig (3) Extinct (4) North-western
(5) Smut (6) *Ustilago* (7) *Staphylococcus* (8) Flemming
(9) *Selaginella* (10) *Pinus*

C. MATCHING TYPE QUESTIONS :

1. Match the terms in Column A with suitable terms in Column B :

Column A	Column B
(i) Phycoerythrin	(a) *Sargassum*
(ii) Fucoxanthin	(b) Diatom
(iii) Chlorophyll	(c) *Spirogyra*
(iv) Absence of pigment	(d) *Porphyra*
	(e) *Harveyella*

2. Match the terms in Column A with suitable terms in Column B : ***(NCERT)***

Column A	Column B
(i) *Chlamydomonas*	(a) Angiosperm
(ii) *Cycas*	(b) Pteridophyte
(iii) *Adiantum*	(c) Algae
(iv) *Rosa*	(d) Gymnosperm
	(e) Fungus

ANSWERS

1. (i) (b); **(ii)** (a); **(iii)** (c); **(iv)** (d) **2. (i)** (c); **(ii)** (d); **(iii)** (b); **(iv)** (a).

D. ASSERTION TYPE QUESTIONS :

These questions consist of two statements each, printed as *Assertion* and *Reason*. While answering these questions you are required to choose any one of the following four responses :

A. If both *Assertion* and *Reason* are true and the *Reason* is a correct explanation of the *Assertion*.
B. If both *Assertion* and *Reason* are true but *Reason* is not a correct explanation of the *Assertion*.
C. If *Assertion* is true but *Reason* is false.
D. If both *Assertion* and *Reason* are false.

1. Assertion : Cyanobacteria is new name for Myxophyceae or blue green algae.
Reason : Brown algae is new name for Chorophyceae.
A **B** **C** **D**

2. Assertion : Red tide is caused by *Gonyaulax*.
Reason : *Gonyaulax* is marine dinoflagellate. They accumulate in sea to provide colour and cause the red tide.
A **B** **C** **D**

3. Assertion : Bioluminescence is exhibited by *Entamoeba*.
Reason : Bioluminescence is the emission of high temperature by living beings.
A **B** **C** **D**

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4. **Assertion :** Algae are characterized by multicellular sex organs in which every cell forms the gamete.
   Reason : Sexual reproduction in algae is only of oogamous type.
   A B C D
5. **Assertion :** Many visitors to hills suffer from skin and respiratory allergy problems.
   Reason : Conifer trees produce a large quantity of wind borne pollen grains.
   A B C D (*AIIMS 2003*)
6. **Assertion :** Protonema of *Funaria* resembles green algae.
   Reason : It forms antheridia and archegonia.
   A B C D
7. **Assertion :** In angiosperms the conduction of water is more efficient because their xylem has vessels.
   Reason : Conduction of water by vessel elements is an active process with energy supplied by xylem parenchyma rich in mitochondria.
   A B C D (*AIIMS 2004*)
8. **Assertion :** Red algae contribute in producing coral reefs.
   Reason : Some red algae secrete and deposit calcium carbonate over their cell walls.
   A B C D (*AIIMS 2004*)
9. **Assertion :** *Chlorella* could serve as a potential source of food and energy.
   Reason : When dried, *Chlorella* has 15% protein, 45% fat, 10% Carbohydrate, 20% fibre, 10% minerals and vitamins.
   A B C D (*AIIMS 2009*)

ANSWERS

1. C; 2. A; 3. D; 4. D; 5. A; 6. C; 7. C; 8. A; 9. C.

E. ANALOGY TYPE QUESTIONS :

1. **Note the relationship between the first two words and suggest a suitable word for the fourth place :**
   (a) Angiosperms :Roots : Rhodophyta :: .....
   (b) Fern : Prothallus :: Moss : .....
   (c) Moss : Capsule :: Fern : .....
   (d) Angiosperms : Flowers :: Conifers : .....

ANSWERS

1. (a) Holdfast; (b) Gametophore; (c) Sporangium; (d) Cones.

F. REASONING TYPE QUESTIONS :

1. Sexual reproduction is of oogamous type in bryophytes.
2. In algae and fungi, plant body is thallus.
3. In red algae and blue green algae bilioproteins are present.
4. Cell wall of red algae protects the brown algae from drying or freezing on their exposure to air.
5. Male sex organs are called antheridia and female sex organs are called archegonia in Bryophytes.
6. *Chlamydomonas* is motile.
7. *Selaginella* bears two types of spores and *Dryopteris* (fern) bears on one type of spores in pteridophytes.
8. Moss like *Funaria* is amphibious in nature.
9. In ferns like *Pteris*, leaf is called frond.
10. Seeds are enclosed by fruit wall or pericarp.
11. Leaves in ferns are large, compound and of megaphyllous type.
12. In *Brassica*, seeds are formed but it is not placed in gymnosperms.
13. Life cycle is diplontic in angiosperms.
14. Double fertilization is present is angiosperms.
15. Diploid (sporophytic) phase is more prominent and long lived and haploid (gametophytic) phase is short lived.
16. In angiosperms, one of the male gametes fuses with egg to form zygote and second male gamete fuses with polar nuclei to form primary endosperm nucleus.

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ANSWERS

1. In oogamous type of reproduction, male gamete is small and motile, female gamete is large and non-motile.
2. It is not differentiated into root, stem and leaves i.e. why they are included under Thallophyta.
3. Due to presence of phycoerythrin and phycocyanin, they are called red and blue green algae.
4. Cell wall in red algae is made of polysulphate esters along with pectic materials.
5. Sex organs are multicellular and jacketed in bryophytes.
6. On anterior end of *Chlamydomonas*, two flagella are present, which makes it motile.
7. Pteridophytes are homosporous or heterosporous.
8. They need moisture for fertilization. It is also due to absence of vascular tissue in bryophytes.
9. *Pteris* leaf is of megaphyll type.
10. In angiosperms ovules form seeds and ovary wall is converted into fruit wall.
11. They called fronds.
12. In *Brassica* seeds are formed in fruits.
13. Haploid (gametophytic phase) is short.
14. Out of two male gametes, one gamete fuses with egg to form zygote and second male gamete fuses with secondary nucleus to form primary endosperm nucleus.
15. Diplontic life cycle is found in angiosperms.
16. It is due to double fertilization.

G. ADDITIONAL MULTIPLE CHOICE QUESTIONS :

Choose the correct answer :

1. The oldest gymnospermous tree is :

   (a) *Zamia pygmia* (b) *Pinus longavaea* (c) *Sequoia sempervirens* (d) *Taxodium mucronatum*

2. Leaves of *Nelumbo* plant are :

   (a) Epistomatic (b) Hypostomatic (c) Amphistomatic (d) None of these

3. Match the following and choose the correct combination from the options given :

	Column I (Group Protista)		Column II (Example)
A	Chrysophytes	i	*Paramoecium*
B	Dinoflagellates	ii	*Euglena*
C	Euglenoids	iii	*Gonyaulax*
D	Protozoans	iv	Diatoms

   (a) A – ii, B – iii, C – ii, D – iv

   (b) A – ii, B – iv, C – iii, D – ii

   (c) A – iv, B – ii, C – iii, D – i

   (d) A – iii, B – iv, C – i D – ii

   (e) A – iv, B – iii, C – ii D – i

4. Consider the following statements regarding the major pigments and stored food in the different groups of algae and select the correct options given.

   (A) In chlorophyceae the stored food material is starch and the major pigments are chlorophyll-*a* and *d*

   (B) In phaeophyceae, laminarin is the stored food and major pigments are chlorophyll-*a* and *b*

   (C) In rhodophyceae, floridean starch is the stored food and the major pigments are chlorophyll-*a*, *d* and phycoerythrin

   Code :

   (a) A is correct but B and C are wrong (b) A and B are correct, but C is wrong

   (c) A and C are correct, but B is wrong (d) B is correct, but A and C are wrong

   (e) C is correct, but A and B are wrong

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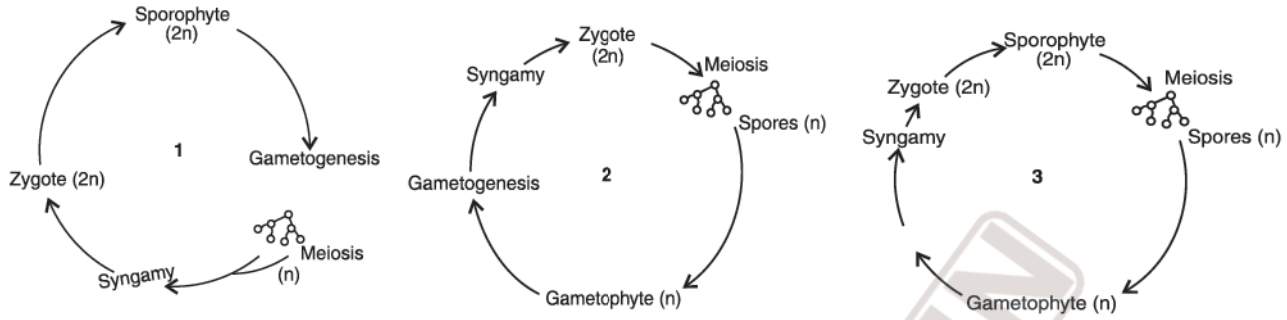
5. Which of the following correctly represents the type of life cycle patterns from the options given ?



Code :

(a) 1. Diplontic 2. Haplodiplontic 3. Haplontic
(b) 1. Haplodiplontic 2. Haplontic 3. Diplontic
(c) 1. Haplontic 2. Diplontic 3. Haplodiplontic
(d) 1. Diplontic 2. Haplontic 3. Haplodiplontic
(e) 1. Haplontic 2. Haplodiplontic 3. Diplontic

6. Choose the wrong pair :

(a) Hepaticopsida – *Marchantia*
(b) Lycopsida – *Selaginella*
(c) Bryopsida – *Anthoceros*
(d) Pteropsida – *Dryopteris*
(e) Sphenopsida – *Equisetum*

7. In which plant, the body represents gametophytic phase and bear haploid gametes :

(a) *Gelidium* (b) *Riccia* (c) *Lycopodium* (d) *Equisetum*

8. *Spirulina* belongs to kingdom :

(a) Monera (b) Fungi (c) Plantae (d) Animalia

9. In which of the following male and female gametophytes do not have free living independent existence ?

(a) *Polytrichum* (b) *Cedrus* (c) *Pteris* (d) *Funaria*

10. Which of the following is heterosporous ?

(a) *Adiantum* (b) *Equisetum* (c) *Dryopteris* (d) *Salvinia*

11. Coralloid root is the feature of :

(a) *Cycas* (b) Mosses (c) *Pinus* (d) *Selaginella*

12. The yielding of rice is increased by :

(a) *Azolla* (b) *Nostoc* (c) *Anabaena* (d) *Clostridium*

13. 'Club moss' belongs to :

(a) Algae (b) Pteridophyta (c) Fungi (d) Bryophyta

14. Cleavage polyembryony occurs in :

(a) *Pinus* (b) Mini *Cycas* (c) *Cycas* (d) *Ephedra*

15. Which of the following pairs are correctly matched :

1. Fertile spike – *Ophioglossum* 2. Sporangiophore – *Equisetum*
3. Synangium – *Psilotum* 4. Apophysis – *Spirogyra*

Code :

(a) 1, 2, 3 are correct (b) 1 and 2 are correct (c) 2 and 4 are correct (d) 1 and 3 are correct

16. Consider the following statements :

Marchantia polymorpha

1. Is dioecious 2. Possesses antheridiophores and archegoniophores

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3. Lacks foot and seta in its sporophyte
4. Is heterosporous

Code :

(a) 1, 2, 3 are correct (b) 1 and 2 are correct (c) 2 and 4 are correct (d) 1 and 3 are correct

17. In *Funaria*, stomata are present on the :

(a) Stem (b) Leaves (c) Capsule (d) Apophysis

18. Which of the following is a prokaryote ?

(a) *Amoeba* (b) *Spirogyra* (c) *Bacteria* (d) *Chlamydomonas*

19. Male gamete in angiosperm is produced by :

(a) Generative cell (b) Microspore cell (c) Vegetative cell (d) Tube cell

20. Meristematic tissue in vascular bundle is :

(a) Phellem (b) Procambium

(c) Interfascicular cambium (d) Fascicular cambium

21. The plant part which consists of two generations one within the other is :

(a) Germinating pollen grain (b) Embryo (c) Unfertilized egg (d) Seed

22. External fertilization occurs in majority of :

(a) Algae (b) Fungi (c) Liverworts (d) Mosses

23. Which of the following combination of characters is true for slime moulds ?

(a) Parasitic, plasmodium without walls, spores dispersed by air currents

(b) Saprophytic, plasmodium without walls, spores dispersed by water

(c) Parasitic, plasmodium without walls, spores dispersed by water

(d) Saprophytic, plasmodium without walls, spores dispersed by air currents

24. In which of the following, pyrenoids are present :

(a) *Chara, Fucus, Polysiphonia* (b) *Volvox, Spirogyra, Chlamydomonas*

(c) *Porphyra, Ectocarpus, Ulothrix* (d) *Sargassum, Laminaria, Gracillaria*

25. Resin and turpentine are products of :

(a) Teak (b) Oak (c) *Eucalyptus* (d) Pine

26. Both chlorophyll *a* and *b* are present in :

(a) Rhodophyceae (b) Phaeophyceae (c) Chlorophyceae (d) None of these

27. Agar-agar is obtained from the following :

(a) *Gelidium* (b) *Nostoc* (c) *Chlamydomonas* (d) *Ulothrix*

28. An alga which is rich in protein is :

(a) *Ulothrix* (b) *Spirogyra* (c) *Nostoc* (d) *Chlorella*

29. Component of cell wall of fungi is :

(a) Cellulose (b) Pectin (c) Chitin (d) Dextrin

30. Which one of the following is an edible fungi ?

(a) *Mucor* (b) *Penicillium* (c) *Rhizopus* (d) *Agaricus*

ANSWERS

1. (b);	**2.** (a);	**3.** (e);	**4.** (e);	**5.** (d);	**6.** (c);	**7.** (b);	**8.** (a);	**9.** (b);	**10.** (d);
11. (a);	**12.** (a);	**13.** (b);	**14.** (a);	**15.** (a);	**16.** (b);	**17.** (c);	**18.** (c);	**19.** (a);	**20.** (d);
21. (d);	**22.** (a);	**23.** (d);	**24.** (b);	**25.** (d);	**26.** (a);	**27.** (a);	**28.** (d);	**29.** (c);	**30.** (d).

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Chapter Practice Test

Time Allowed : 1:30 Hours *Maximum Marks : 35*

1. Define alternation of generations. (1)
2. What are elaters? (1)
3. Which type of venation is present in ferns? (1)
4. Which type of sperms are present in *Cycas*? (1)
5. What is protonema? (1)
6. Most algal genera show haplontic life cycles. Name algae which show (a) Haplodiplontic (b) Diplontic life cycles (2)
7. What is the ecological importance of pteridophytes? (2)
8. What are bogs? (2)
9. Name three groups of plants which bear archegonia. (2)
10. Mention ploidy of the following:
    (i) Zygote (ii) Ovum (iii) Gemma of *Marchantia* (iv) Prothallus of ferns (2)
11. How is natural system of classification different from artificial system of classification? (2)
12. What is heterospory? Write its significance. (2)
13. Demonstrate alternation of generations in ferns. (3)
14. Both gymnosperms and angiosperms bear seeds. Why they have been classified separately? (3)
15. Define (a) Cytotaxonomy (b) Chemotaxonomy (3)
16. Describe various methods of asexual reproduction in algae. (5)

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To check your performance, see ANSWERS TO CHAPTER PRACTICE TEST at the end of Part I of the book.

CHAPTER 4

ANIMAL KINGDOM

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NEED OF CLASSIFICATION

There are about **7.77 million animal species** (of which 953, 434 animal species have been described and catalogued) which show a great diversity of life. Though the animals are metozoans like the plants but these differ from plants in a number of characters like **absence of plastids, cell wall and central vacuole;** and having **centrosome** in their cells. These are exclusively **heterotrophic** and are **mostly holozoic** in their nutrition. These also pass through certain **larval stages** during their development.

According to their mode of living, animals may be **solitary** (found alone *e.g.* **Tapeworm**) or **gregarious** (live in groups but without obligatory interactions *e.g.* **Locust)** or **colonial** (live in a social hive and show obligatory interdependence *e.g.* **honey bees, wasps, termites,** etc.) These may be **free living** or **sedentary**.

The free living organisms develop certain **organs of locomotion** to locate their food, shelter or mate, while the sedentary animals. *e.g.*, **sponges,** maintain a water current to draw food to them.

Another peculiar character of animals is the presence of some kind of **receptors or nervous system** to guide and inform them about their environment. These systems receive stimuli from the environment and respond by showing certain animal behaviour. Notable exceptions are sponges which do not have nerve cells.

So to express the relationship between different organisms, there is **need of classification.** It involves arrangement of organisms into different groups on the basis of their similarities and differences. So classification helps in assigning a **definite taxonomic systematic position** to a species.

GENERAL FEATURES OF ANIMALS AS BASIS OF CLASSIFICATION HABITAT

Definition. It is the place where an organism lives. On the **basis of habitat,** animals are divided into the following categories :

(a) Aquatic animals. These are those animals which are found in water. On the basis of nature of water, aquatic animals may be **marine** (those found in sea-water *e.g.*, **all echinoderms** and **cartilage fishes;** and **most of sponges** and **coelenterates**) or **fresh-water** animals (those found in ponds, rivers, streams etc. *e.g. Amoeba, Paramecium,* **Prawn** etc.).

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(b) Terrestrial animals. These animals live on land and are again of following types :

(i) Fossorial animals. These live inside the burrows *e.g.*, **earthworm, snake, rabbit** etc.

(ii) Arboreal animals. These live on the trees *e.g.*, **most of birds, bats, monkeys** etc.

(iii) Scansorial animals. These climb the walls, rocks etc. *e.g.*, **wall lizards, flying squirrels** etc.

(iv) Aerial animals. These can go in air *e.g.*, **most of insects and birds, bats** etc.

(v) Cursorial animals. These are fast-runners *e.g.*, **horse, rabbit, lion** etc.

LEVELS OF ORGANISATION

Animals are divided into **four categories** on the basis of their **organisation :**

1. Cellular organisation. The animal body is formed of loosly arranged **cell aggregates** but the cells show **no coordination** to form tissues *e.g.*, **sponges.** In them, division of labour occurs at cellular level.

2. Tissue organisation. The animal body is formed of many cells which coordinate for the specific function and form four types of tissues *e.g.*, epithelial tissue, connective tissue, muscular tissue and nervous tissue *e.g.*, **coelenterates** like *Hydra* and **Ctenophores.**

3. Organ level organisation. In this, tissues coordinate to form organs to perform specific function e.g. **Platyhelminthes** (*Fasciola*).

4. Organ-system organisation. The body is multicellular and organs coordinate to form systems, each specialised for a specific function *e.g.*, from **Roundworms to mammals.**

BODY PLAN

A **body plan** is a group of structural and developmental characteristics that can be used to identify a group of animals. The shape and size of the animals show great diversity and on these basis, animals have **three types of body plan :**

1. Cell aggregate plan (Fig. 1 A). In this, the body is just an aggregate of cells with no coordination between them and little differentiation *e.g.*, **sponges.**

2. Blind sac plan (Fig. 1 B). In this, multicellular animal has tissue or organ-system organisation but there is **incomplete alimentary canal** in which single opening acts as both **mouth** (for ingestion) and **anus** (for egestion) *e.g.*, **flatworms** (*Fasciola hepatica* — liver fluke). It is also found in **coelenterates** (*Hydra*).

3. Tube-within-a-tube plan (Fig. 1 C). In this, multicellular animal has organ-system organisation and is with **complete alimentary canal** having two separate openings — **mouth** for ingestion at the anterior end and **anus** or **cloacal aperture** for egestion at the posterior end. It is again of **two types :**

(a) Protostomous (Fig. 1 C). In this, blastopore of archenteron of gastrula larva forms mouth and is formed earlier than anus *e.g.*, in **roundworms, annelids, molluscs** and **arthropods.**

(b) Deuterostomous (Fig. 1 D). In this, blastopore of gastrula forms anus, so anus is formed earlier than mouth *e.g.*, in **echinoderms** and **chordates.**

SYMMETRY

It is the arrangement of similar body parts on two sides of main axis of body. On the basis of **symmetry,** animals are of **two types :**

1. Asymmetrical animals and 2. Symmetrical animals.

1. Asymmetrical (Fig. 2 A). When body cannot be divided in two similar parts from any direction *e.g.*, *Amoeba*, **snails, certain sponges.**

2. Symmetrical. When body can be divided in two similar parts which are mirror images of each other by **one or more planes.** On the basis of **planes of division,** symmetry in animals is of **three types :**

(a) Spherical or Universal Symmetry (Fig. 2B). When body can be divided into two similar parts by **any plane passing through the centre** of body *e.g.*, *Volvox* and radiolarian protozoans.

(b) Radial Symmetry (Fig. 2 C). Body can be divided in two similar parts by **any plane along central axis of body** *e.g.*, **coelenterates, ctenophores** and **echinoderms.**

(c) Bilateral Symmetry (Fig. 2 D). Body can be divided in two similar parts by only one plane along **longitudinal axis** of body *e.g.*, **annelids, arthropods and vertebrates.**

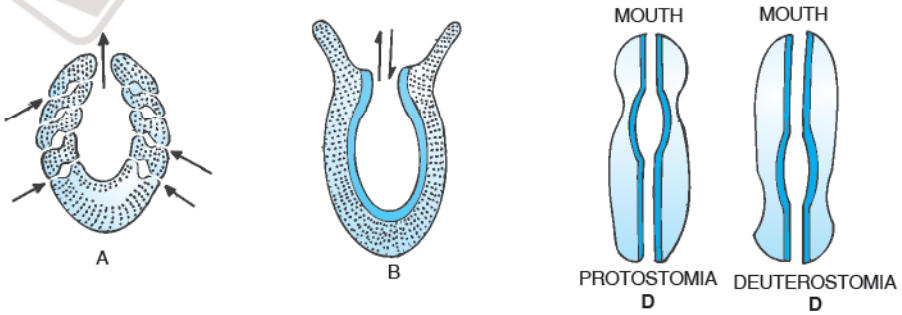

Fig. 1. Types of Body plan **A.** Cell Aggregate plan. **B.** Blind Sac Plan. **C & D.** Tube-within-a-tube plan.

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Table 1. Differences between Protostomes and Deuterostomes.

Characters	Protostomes	Deuterostomes
1. Fate of blastopore	Forms mouth.	Forms anus.
2. Cleavage	Spiral and determinate.	Radial and indeterminate.
3. Examples	Roundworms, annelids, molluscs and arthropods.	Echinoderms and chordates.

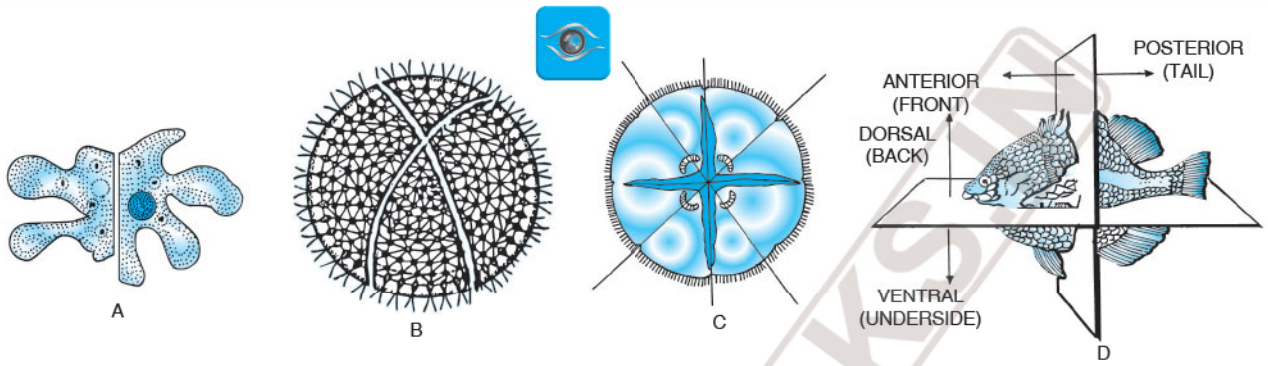

Fig. 2. Types of symmetry. **A.** Asymmetry—*Amoeba.* **B.** Spherical - *Volvox.* **C.** Radial - *Aurelia.* **D.** Bilateral - Fish.

SEGMENTATION (METAMERISM)

In annelids, arthropods, and vertebrates, there is repetition of internal body parts which is termed **metamerism.** It is not found in roundworms, molluscs and echinoderms.

In annelids (*e.g.*, **earthworm**), body is externally divided into segments called **metameres** or **somites** by grooves called **annuli** and body cavity is internally divided by **septa.** External division corresponds to internal division and is called **metameric segmentation.**

But in the vertebrates, there is only internal metamerism as shown by repetition of ribs, vertebrae, nerves, muscles etc., while metamerism is only external in arthropods.

COELOM (BODY CAVITY)

Coelom is the space between body wall and gut wall and is lined by mesoderm. It helps in classification of animals. On the basis of **nature of coelom,** animals are divided into the following categories:

1. Acoelomates. Among invertebrates **upto flatworms,** there is no coelom and they are called **acoelomates** (Fig. 3 A). In flatworms, semisolid mesodermal tissues hold the body organs in place.

2. Pseudocoelomates. In **Aschelminthes** (roundworms *e.g.*, *Ascaris*), coelom is present but is only partly lined by the tissues derived from mesoderm and is called **pseudocoel** or **false-coelom,** so the roundworms are **pseudocoelomates** (Fig. 3 B). Mesodermal pouches are present between ectoderm and endoderm.

LEARNING PLUS

- Radial symmetry (R.S.) is again of following types:
  — **Tetramerous R.S.** : Body parts arranged in four or multiple of four *e.g.*, **Jellyfish.**
  — **Pentamerous R.S.** : Body parts arranged in five or multiple of five *e.g.*, **echinoderms.**
  — **Hexamerous R.S.** : Body parts arranged in six or multiple of six *e.g.*, **sea anemone.**
- The animals with radial symmetry have only oral and aboral sides.
- On the basis of their feeding, the animals are called:
  — **Herbivores** : Eat upon only vegetable food *e.g.* cow, buffalo, sheep, goat, etc.
  — **Carnivores** : Eat upon only animal food *e.g.* frog, lion, tiger, etc.
  — **Omnivores** : Eat upon both vegetable and animal food *e.g.* cockroach, human beings, etc.
  — **Sanguivores** : Feed upon blood of other animal *e.g.* leech, bed bug, etc.
  — **Frugivorous** : Feed upon fruits *e.g.* flying fox, parrot, etc.
  — **Saprophagous** : Feed upon dead organic matter *e.g.* earthworms.
  — **Coprophagous** : Feed upon faeces *e.g.* pigs, etc.
- **Biradial symmetry** : When body can be divided into two similar parts by two vertical planes but the parts formed by one plane are not similar to those formed by other plane *e.g.* **sea anemones** and **comb jellies.** It represents a combination of radial and bilateral symmetry.
- For sessile animals (e.g. **sponges**), radial symmetry is advantageous as it allows capturing of food from all the sides, while for nektonic and benthonic animals, bilateral symmetry is advantageous as these show cephalization.

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R U CURIOUS

- **Cephalization** is differentiation of head at anterior end of body.
- **Schizocoelic coelom :** Body cavity formed by splitting of mesoderm *e.g.*, annelids, arthropods and molluscs.
- **Enterocoelic coelom :** Body cavity formed from the enteron of gastrula *e.g.*, echinoderms and chordates.
- Alimentary canal is absent in sponges and tapeworms.
- Pseudocoel is developed from blastocoel.
- Bilateral symmetry has a number of advantages like cephalization, streamlining of body and more efficient unidirectional movements.

3. Eucoelomates. From **annelids to mammals,** body cavity is present between mesodermal peritoneal layers. These are **parietal peritoneum** on outer side and **visceral peritoneum** on inner side. It is called **true-coelom,** so these are called **true coelomate** or **eucoelomates** (Fig. 3 C).

4. Haemocoelomates. In **Arthropods** and **molluscs,** true coelom is reduced and body cavity is a pseudocoel with blood and is called **haemocoel** and animals are called **haemocoelomates.**

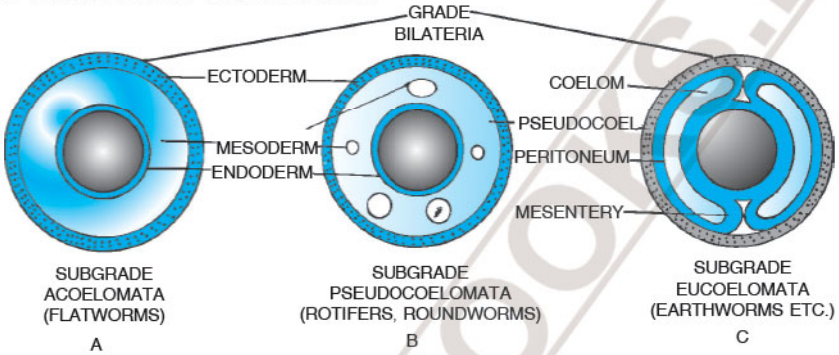

Fig. 3. A. Acoelomate. **B.** Pseudocoelomate. **C.** Eucoelomate.

GERM LAYERS

The layers of gastrula from which all the body-organs are formed, are called **germ-layers.** These give rise to all the tissues of an animal during the process of organogenesis.

On the basis of **number of layers,** the animals are divided into **two categories :**

1. Diploblastic animals. In **sponges, coelenterates,** and **ctenophores,** gastrula is with two layers, outer **ectoderm** and inner **endoderm,** so are called **diploblastic animals.**Between these germ layers, an undifferentiated, non-cellular and gelatinous **mesoglea** is present.

2. Triploblasic animals **(Fig. 4).** From **flatworms** to **mammals,** gastrula larva is with three germ layers, outer ectoderm, middle **mesoderm** and inner **endoderm**. So these are called **triploblastic animals.**

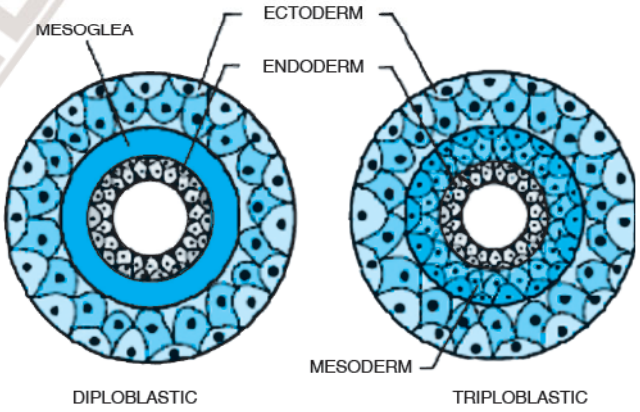

Fig. 4. Primary germ layers.

RESPIRATORY SYSTEM

In sponges and coelenterates, every cell of body is in direct contact with surrounding water and exchange of gases occurs through **their body surface.** But higher animals have thick body wall so they have special **respiratory organs** and **modes of respiration.** These are summarised in Table 2.

Table 2. Modes of Respiration.

Mode of respiration	Respiratory organ	Examples
1. **Body-surface respiration**	Body-surface	**Sponges Ctenophores** and **coelenterates** (*Hydra*)
2. **Branchial respiration**	Gills	**Crustaceans** (Prawn), **Cartilage** and **bony fishes.**
3. **Cutaneus respiration**	Skin.	**Annelids** (earthworm) and **amphibians** (frog)
4. **Tracheal respiration**	Tracheae (ectodermal tubes)	**Insects** (cockroach). **Centipedes, millipedes.**
5. **Pulmonary respiration**	Lungs.	**Most of tetrapods.**
6. **Book-lung respiration**	Book-lungs.	**Arachnids** (spiders and scorpions).
7. **Book-gill respiration**	Book-gills.	*Limulus* **(King-crab)**
8. **Cloacal respiration**	Cloaca	Some turtles.

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CIRCULATORY SYSTEM

It transports the materials inside the body. It is of **two types :**

1. Open Circulatory System. In this type, blood comes out of blood vessels in spaces called **sinuses.** It is found in **arthropods,** most of **molluscs** and **leeches.** In this, blood flows at slow speed and low pressure.

2. Closed Circulatory System. In this type, blood remains inside the blood vessels (arteries, veins and capillaries). It is found in most of **annelids** and all **vertebrates.** In this, blood flows at faster speed and high pressure.

Arthropods and **molluscs** have body cavity which is filled with blood and is called **haemocoel,** Colour of blood depends upon pigments present in blood *e.g.,*

In **earthworm,** blood is **red** due to an iron-containing **erythrocruorin** present in plasma, while it is green in some polychaetes due to green-coloured pigment **chlorocruorin.**

In **vertebrates,** blood is **red** due to **haemoglobin in RBCs.**

In **molluscs,** blood is **blue-coloured** due to copper-containing **haemocyanin** in **plasma.**

In **insects,** blood is colourless (no pigment) and is called **haemolymph.**

EXCRETORY SYSTEM

It expels the nitrogenous wastes (excretion) out of the body to maintain **homeostasis** inside the body. Different animal groups have different excretory structures **(Table 3)** :

These excretory organs perform two functions : **excretion** and **osmoregulation** (maintaining water level in the body).

On the basis of nature of **main nitrogenous waste,** excretion is of **three types :**

(i) Ammonotelism. When main nitrogenous waste is NH_3 and the animals are called **ammonotelic animals.** It is found in aquatic animals *e.g.,* **sponges, coelenterates, ctenophores, crustaceans, echinoderms** and **bony fishes.**

(ii) Ureotelism. The main nitrogenous waste is **urea** and the animals are called **ureotelic animals.** It is found in **amphibians, mammals** and **cartilage fishes.**

(iii) Uricotelism. Main nitrogenous waste is **uric acid** and animals are called **uricotelic animals.** It is found in **reptiles, birds** and **insects.**

NERVOUS SYSTEM

It controls and coordinates the body functions to maintain homeostasis inside the body. It is absent from sponges and is of different type in different groups of animals **(Table 4)** :

Table 3. Excretory organs found in different groups of animals.

Animal groups	Excretory organs
1. Porifera and Coelenterata	By diffusion through body surface
2. Platyhelminthes (Flatworms)	Protonephridia (flame cells)
3. Aschelminthes (Round worms)	Excretory canals (Renett cell)
4. Annelids (Segmented worms)	Nephridia
5. Crustaceans (*e.g.* Prawn)	Antennary or green glands
6. Arachnids (e.g Scorpion)	Coxal glands and Malpighian tubules (in some spiders)
7. Insects, centipedes and millipedes	Malpighian tubules and urate cells.
8. Molluscs	Metanephridia
9. Vertebrates	Kidenys

Table 4. Type of nervous system found in different animal groups.

Animal Group	Type of Nervous System
1. **Coelenterates**	**Diffuse type** (nerve fibres not differentiated into dendrons and axon).
2. **Flatworms and roundworms**	**Ladder type** (formed of a nerve ring and many nerve cords which are interconnected by connectives).
3. **Annelids**	**Central nervous system** (CNS) formed of a **circumpharyngeal nerve ring** and ventral, single, solid and ganglionated **nerve cord.**
4. **Arthropods**	CNS is formed of a **circum-oesophageal nerve ring** and a double, ventral, solid and ganglionated **nerve cord.**
5. **Molluscs**	Formed of a few ganglia interconnected by some commissures and connectives.
6. **Echinoderms**	**Two nerve rings** (oral and aboral) and radial nerves.
7. **Vertebrates**	CNS formed of anterior broader **brain** and posterior longer and narrow **spinal cord.** CNS is dorsal, hollow and non-ganglionated.

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REPRODUCTION

Reproduction is a peculiar feature of all the living organisms and is essential for the survival and continuation of race. Many individuals reproduce only by **asexual methods**. Common methods of asexual reproduction are : **Binary fission** (parent organism dividing in two during favourable conditions e.g. *Amoeba*); **Multiple fission** (parent dividing in many daughter cells during unfavourable conditions e.g. *Amoeba*); **Budding** (parent developing external or internal outgrowths called **buds** e.g. *Hydra) and* **fragmentation.** Most of organisms undergo **sexual reproduction** (which involves formation and fusion of gametes). Gametes are the sex cells. These are formed in the sex organs called **gonads**. Gonads are called **testes** in male and **ovaries** in female while sex cells of male and female are called **sperms** and **ova** respectively. In most of animals, two types of gonads are present in different animals and are called **unisexual or dioecious** *e.g.* human beings, frog, cockroach etc.

When in unisexual animals, two sexes are externally different in their structure, the condition is called **sexual dimorphism** *e.g.*, peacock and peahen, human beings etc. But in some animals, both types of gonads (testes and ovaries) are present in same animal, and are called **bisexual** or **monoecious** or **hermaphrodite** *e.g.*, **earthworm, leech**, *Taenia* etc.

Fusion of sperm and ovum is called **fertilization** while fusion-product is called **zygote.** Fertilization may be **external** (echinoderms, bony fishes and amphibians) or **internal** (land vertebrates and cartilage fishes) depending upon whether fusion occurs outside or inside the body of female.

In unisexual animals, sperms and ova are derived from different animals, called **cross-fertilization.** In some bisexual animals, sperm and ovum of same animal fuse, called **self-fertilization** *e.g.*, in *Taenia*. But in some bisexual animals, cross-fertilization occurs due to two conditions : **protandrous** and **protogynous.** In **protandrous condition** (*proto* = first, *androus* = male), testes mature earlier than ovaries *e.g.* **leech, earthworm** etc. In **protogynous condition** (*proto* = first, *gynae* = female), ovaries mature earlier than testes *e.g.*, *Scypha*, *Herdmania* **(Sea squirt).**

On the basis of **breeding behaviour,** females are of **two types (Table 5) :**

Table 5. Differences between Oviparity and Viviparity (Fig. 5).

Oviparity	Viviparity
1. Female lays **eggs**.	1. Give birth to **young-ones**.
2. **Fertilization** may be external or internal.	2. Always internal.
3. Egg is generally yolky and large sized.	3. Egg is small sized and generally non-yolky.
4. **Development** occurs outside female.	4. Always inside female.
5. **Placenta** is not formed. *e.g.*, **All birds, amphibians, most of fishes and insects.**	5. Placenta is formed. *e.g.*, **Most of mammals.**

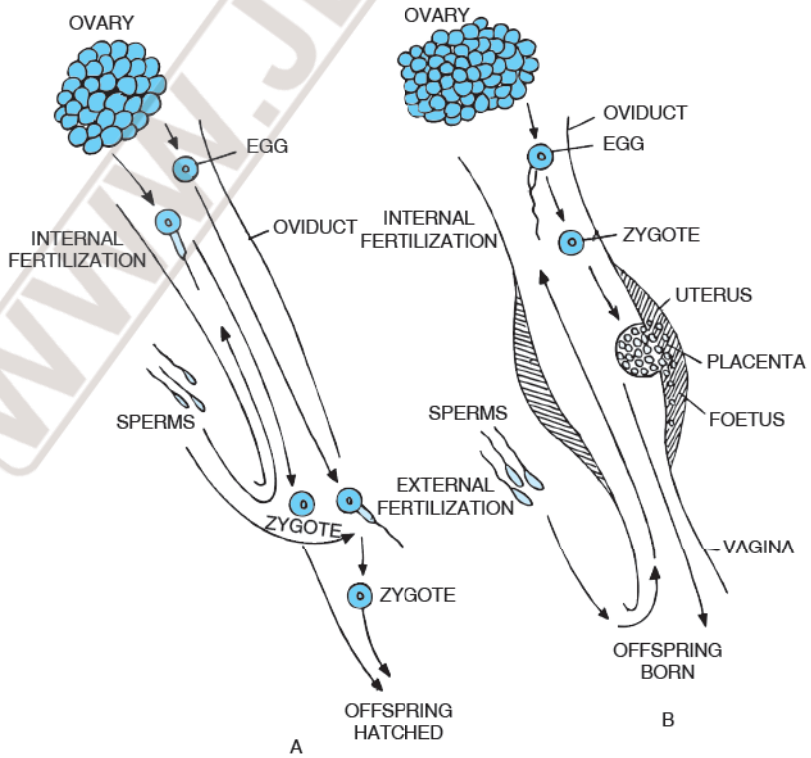

Fig. 5. Breeding behaviour of female. **A.** Oviparity. **B.** Viviparity.

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BODY TEMPERATURE

On the basis of body temperature, animals are divided into **two categories :**

1. Homeothermal (Warm-blooded or endothermic animals). In this, **body temperature is constant** and does not change with the change in environmental temperature *e.g.*, **birds** and **mammals.**

2. Poikilothermal (Cold-blooded or ectothermic animals). In this, **body temperature is not constant** and changes with change in environmental temperature. e.g. **amphibians** and **lizards.**

SKELETON

Any hard structure of body which gives shape, support and protection to the body is called **skeleton.** On the **basis of position,** skeleton is of **two types :**

1. Endoskeleton. It is always present inside the body and is generally formed of living structures *e.g.*, **cartilages** and **bones.** *e.g.*, vertebrates.

2. Exoskeleton. It is always present outside body. It is always formed of dead structures *e.g.*, chitinous plates called **sclerites** in arthropods; **calcareous shell** in molluscs; **epidermal scales in** reptiles; epidermal **feathers** in birds; epidermal **hair, nails, claws, horns** and **hoofs** in mammals.

NOTOCHORD

It is a solid and unjointed mesodermal rod of vacuolated cells present on dorsal side between alimentary canal and nervous system in some animals. It acts as **primary axial skeleton.** On the basis of presence or absence of notochord, animals are divided into **two categories :**

1. Non-chordates : These animals lack notochord e.g. **poriferans to hemichordates.**

2. Chordates : These possess notochord at least in some stages of life cycle e.g. **vertebrates.**

Table 6. Differences between Poikilothermal and Homeothermal animals.

Characters	Poikilothermal (cold-blooded)	Homeothermal (warm-blooded)
1. Body temperature	Comparatively low and changes with changes in environmental temperature.	High and constant so does not change with change in environmental temperature.
2. Metabolic rate	Low.	High.
3. Hibernation	Undergo hibernation during winter months.	Donot undergo hibernation.
4. Examples	Fishes, amphibians and reptiles.	Birds and mammals.

Table 7. Differences between Endoskeleton and Exoskeleton.

Characters	Endoskeleton	Exoskeleton
1. Position	Inside the body.	Outside the body.
2. Nature of elements	Living structures.	Dead structures.
3. Type of elements	Cartilages and bones.	• Sclerites of arthropods; • Shell of molluscs; • Epidermal scales in reptiles; • Feathers in birds; • Hair, nails, horns, hoofs in mammals.

COMPETITION PLUS

- **Metamorphosis :** Sum of all the changes which transform a larva into the adult.
- **Progressive metamorphosis :** Simple larva changes into complex adult *e.g.*, **frog.**
- **Retrogressive metamorphosis :** Advanced larva changes into a degenerate adult *e.g.*, *Herdmania*
- **Hibernation :** Period of inactivity in winter months so also called **winter sleep** *e.g.* **amphibians** (frog) and **lizards.**
- **Aestivation :** Period of inactivity in summer months so also called **summer sleep** *e.g.* **frog.**
- Cold blooded animals cannot survive in cold alpine and arctic areas. These are active in hot deserts for limited period only.
- **Aminotelism :** Main nitrogenous wastes are amino acids. It is found in star fish, sea cucumber, *Unio*, etc.

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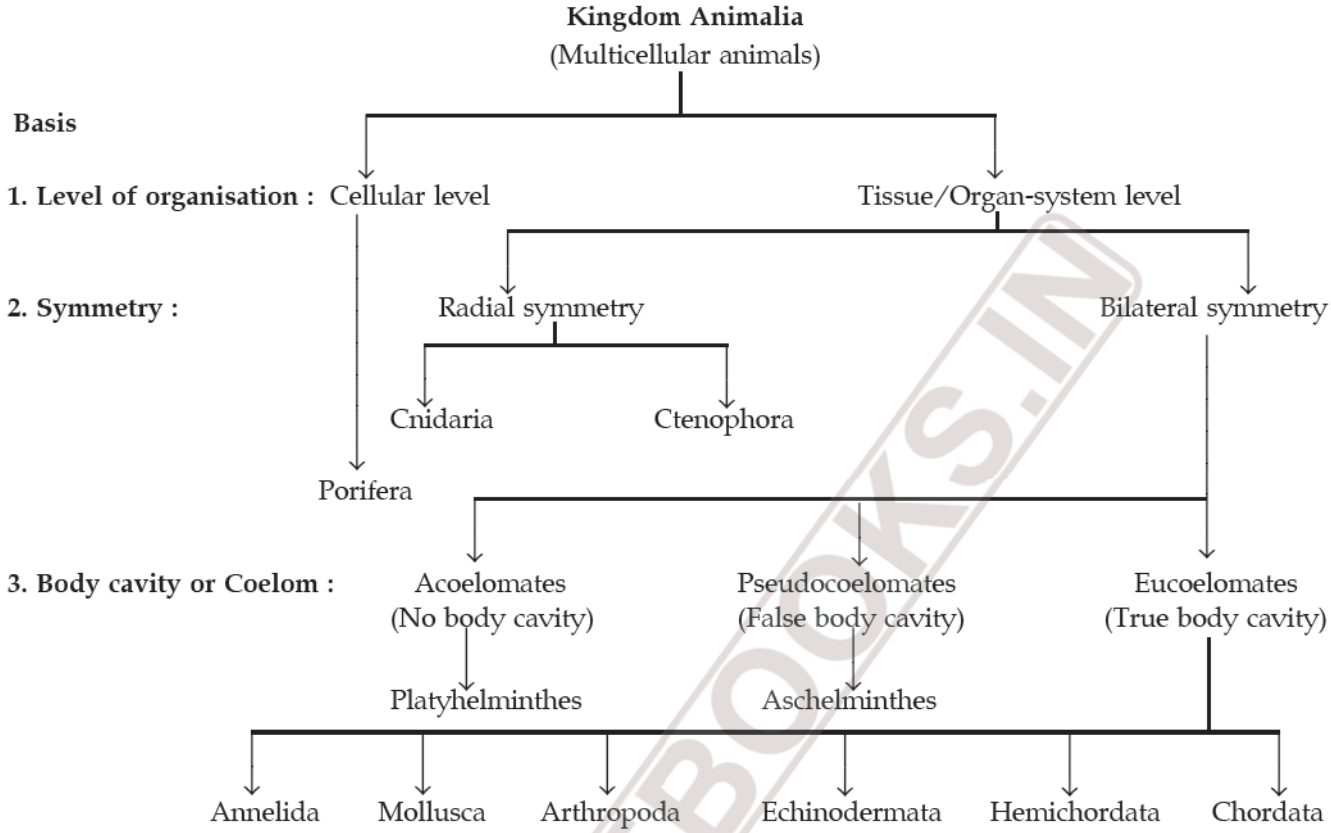
Table 8. Broad classification of kingdom Animalia based on common fundamental characters.



PRACTICE PROBLEMS—GENERAL CHARACTERS OF KINGDOM ANIMALIA

1. How do nektonic and benthonic animals differ from each other?
2. Give one example of each of cellular and tissue organisation.
3. What are deuterostomous animals? Give one example.
4. What are protostomous animals? Give one example.
5. Differentiate radial symmetry and bilateral symmetry.
6. Define metameric segmentation.
7. What are pseudocoelomates? Give one example.
8. Define haemocoel. Name two groups of animals in which it is present.
9. Name the respiratory organs of insects and scorpion.
10. How do diploblastic and triploblastic animals differ from each other?
11. What is closed circulatory system? Name two groups of animals having this type of circulation.
12. Name the excretory organs of annelids and insects.
13. Which type of nervous system is found in flat worms?
14. Define sexual dimorphism.
15. What is hermaphroditism? Name two hermaphroditic animals.
16. What are viviparous animals? Name a non-mammal viviparous animal.
17. What do you mean by poikilothermal nature? Name two groups of animals with such a condition.
18. Define retrogressive metamorphosis. Give one example.
19. What is hibernation? What is its significance?
20. Name two endoskeletal elements.

ANSWERS TO PRACTICE PROBLEMS

1. **Nektonic** are actively swimming animals (e.g. fishes), while **benthos** are bottom dwellers (e.g. sponges).
2. (i) Cellular organisation = **sponges;** (ii) Tissue organisation = **coelenterates.**
3. Animals in which blastopore of gastrula forms **anus** e.g. echinoderms and chordates.
4. Animals in which blastopore forms **mouth** e.g. arthropods, annelids, etc.

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5. In **radial symmetry,** body can be divided into two similar halves by any plane passing through the centre; while in **bilateral symmetry**, body can be divided into two similar halves by only one plane along longitudinal axis of body.
6. When external division of body by annuli corresponds to internal division of coelom by septa e.g. in **annelids.**
7. Animals having false body cavity called **pseudocoel** e.g. nematodes like *Ascaris.*
8. A pseudocoel with blood is called **haemocoel** e.g. arthropods and molluscs.
9. (i) Insects = **Tracheae;** (ii) Scorpion = **Book lungs.**
10. Diploblastic animals develop from 2 **primary germ layers** of gastrula (e.g. **sponges**), while triploblastic animals are developed from 3 **primary germ layers** (e.g. flatworms to mammals).
11. In this, blood always flows **in the blood vessels only** e.g. all the vertebrates and most of annelids.
12. (i) Annelids = **Nephridia;** (ii) Insects = **Malpighian tubules.**
13. **Ladder - type** nervous system.
14. When two sexes of a species are different in their morphology and physiology e.g. cockroach, human beings, etc.
15. When an animal has **both types of sex organs** (e.g. testes and ovaries) e.g. earthworm, and leech.
16. Animals which **give birth** to youngones e.g. sea snake.
17. These have **variable body temperature** which changes with change in environmental temperature e.g. fishes, amphibians and reptiles.
18. When an advanced larva changes into a degenerate adult e.g. *Herdmania.*
19. Also called **winter sleep** in which animal hides itself and becomes inactive in winter months. It protects the animals in unfavourable conditions.
20. Cartilages and bones.

Table 9. Classification of kingdom Animalia.

Kingdom Animalia is divided into **35 phyla** (sing. **Phylum)** of which 11 are considered as **major phyla** and rest are called **minor phyla.** About 95% per cent of animals are without backbone and are called **invertebrates,** while the animals having a backbone, are called **vertebrates.**

On the basis of **notochord,** kingdom Animalia is divided into **two sections :**

Section I. Non-chordata
(Notochord is absent in some stages of development)

Non-chordata accounts for 95% of total animal species and is divided into following phyla :

- Phylum **Porifera** (Sponges)
- Phylum **Coelenterata** (Cnidarians)
- Phylum **Ctenophora** (Comb jellies)
- Phylum **Platyhelminthes** (Flatworms)
- Phylum **Aschelminthes** (Roundworms)
- Phylum **Annelida** (Segmented worms)
- Phylum **Arthropoda** (Animals with jointed legs)
- Phylum **Mollusca** (Soft-bodied animals)
- Phylum **Echinodermata** (Spiny-skinned animals)
- Phylum **Hemichordata** (Half chordates)

Section II. Chordata
(Notochord is present at least

On the basis of **fate of notochord,** Chordata is divided into **3 sub-phyla** :

- **Sub-Phylum Urochordata** (Notochord only in the tail of larval stage)
- **Sub-Phylum Cephalochordata** (Notochord extends upto the tip of head)
- **Sub-Phylum or Division Vertebrata** (Notochord replaced by vertebral column)

On the **basis of Jaws,** Vertebrata is divided into **2 sub-divisions:**

- **Agnathostomata** (Jaws absent)
  - Single class - **Cyclostomata**
- **Gnathostomata** (Jaws present)
  - On the basis of **locomotory organs,** it is divided into **2 super classes :**
    - **Super-class Pisces** (Locomotion by fins)
      - Divided in **2 classes** on the basis of skeleton :
        - **I. Chondrichthyes** - Cartilage fishes.
        - **II. Osteichthyes** - Bony fishes.
    - **Super-class Tetrapoda** (Locomotion by four limbs)
      - Divided in **4 classes** on the basis of **skin :**
        - **I. Amphibia** - Skin is thin and moist.
        - **II. Reptilia** - Skin covered by epidermal scales
        - **III. Aves** - Skin covered by feathers
        - **IV. Mammalia** - Skin covered by hair.

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ADDITIONAL USEFUL INFORMATIONS ABOUT GENERAL CHARACTERS OF KINGDOM ANIMALIA FOR COMPETITIVE EXAMINATIONS

- ***Radiata :*** *Group including radial symmetrical animals e.g.* ***sponges, coelenterates*** *and* ***echinoderms.***
- ***Bilateria :*** *Group including bilaterally symmertical animals e.g.* ***flatworms, roundworms, annelids, arthropods, molluscs*** *and* ***vertebrates.***
- ***Pseudometamerism*** *: New segments are formed from the neck (anterior side of body) by transverse fission called* ***strobilation.*** *It is found in* ***tapeworms.***
- *Blood vascular system is absent upto round worms. Annelids are first animals to have blood vascular system.*
- *Sponges and coelenterates have* ***water circulation****, flat worms are with* ***parenchymal circulation****, while nematodes have* ***pseudocoelomic circulation.***
- ***Blastocoel*** *: Also called* ***segmentation cavity:*** *Cavity of blastula.*
- ***Archenteron*** *: Cavity of gastrula.*

NON-CHORDATA

PHYLUM PORIFERA

(Gr. *pori* = **pores;** *pherein* = **bearing**) **(The sponges)**

Characters :

1. These are **Pore-bearing animals** and are commonly called **sponges.** Pores are of two types: numerous and smaller **ostia** and one or few larger **oscula** which act as inlets and outlets of water currents.

2. These have **cellular organisation** and **cell aggregate plan,** and are mostly **asymmetrical.**

3. These are **diploblastic** animals. The adult body wall is formed of 2 layers : outer **dermal layer or pinacoderm** of flat **pinacocytes** (Fig. 6 A) and inner **gastral layer or choanoderm** of flagellated **collar cells** or **choanocytes** (Fig. 6 B) whose flagella beat and maintain a water current. Between two layers, there is a gelatinous and non-cellular **mesoglea** or **mesenchyme** and has many types of **amoebocytes.**

4. These are **omnivorous** and **holozoic** in nutrition and digestion is **intracellular.**

5. Sponges lack mobility, sensory and nerve cells.

6. Respiration and **excretion** occur through general body surface. These are **ammonotelic.**

7. These are **mostly marine** but about 150 sponge species inhabit fresh-water habitats e.g. *Spongilla.*

8. These have a peculiar **canal system** (of interconnected canals) whose central cavity is called **paragastric cavity or spongocoel.** A water current flows through canal system and helps in nutrition, respiration, excretion and reproduction.

9. These have an **endoskeleton** of either **calcareous spicules** (needles made up of $CaCO_3$) or **silicious spicules** (needles made up of silicic acid) or of **spongin fibres.**

10. Asexual reproduction generally occurs by **fragmentation or external budding** or **gemmules** (Fig. 6C) (Internal buds).

11. These have **very high power of regeneration.**

12. Most of sponges are **bisexual** or **hermaphrodite** or **monoecious.** Fertilization is internal. Development is indirect and includes a free-swimming **amphiblastula larva** (half flagellated and half non-flagellated) or **parenchymula larva** for dispersal.

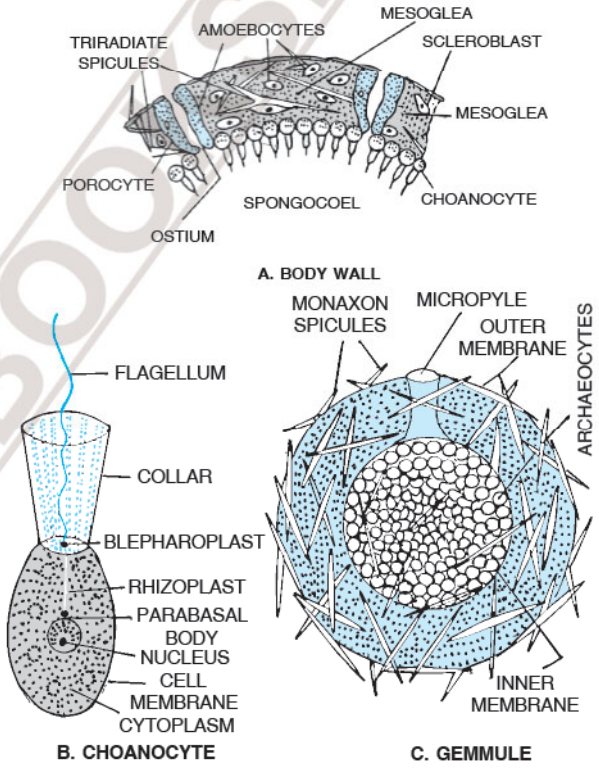

Fig. 6. Characteristics of Sponges.

There are about **5,000 living species** of sponges.

CLASSIFICATION OF PORIFERA FOR COMPETITIVE EXAMINATIONS

Porifera is divided into **three classes** on the basis of **endoskeletal elements :**

A. Class Calcispongiae or Calcarea (*L. calx* = lime). Endoskeleton is formed of **calcareous spicules** (of $CaCO_3$) *e.g., Leucosolenia* (simplest known sponge), *Scypha* **(Sycon).**

B. Class Hexactinellida or Hyalospongiae (Gr. *hyalose* = glass, *spongos* = sponge). Endoskeleton is formed of 6-rayed siliceous spicules *e.g., Euplectella* **(Venus - flower basket)** and *Hyalonema* **(Glass-rope sponge).**

C. Class Demospongiae (Gr. *demos* = frame; *spongos* = sponge) Endoskeleton is formed of either **spongin fibres** or other siliceous spicules (**1-4** rayed) or both *e.g., Euspongia* **(Bath sponge)**, *Spongilla* **(Fresh-water sponge).**

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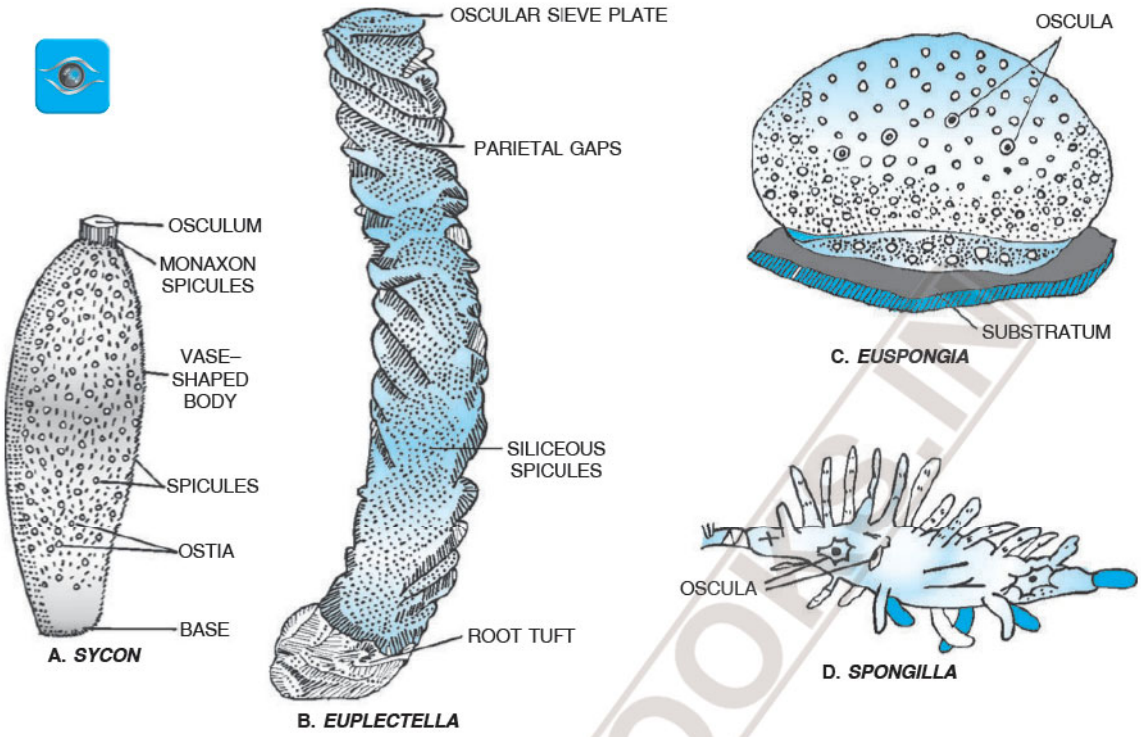

Fig. 7. Important Poriferans.

Examples (Fig. 7) : *Scypha* (Sycon), *Spongilla*, *Chalina* (Dead man's finger sponge), *Cliona* (Boring or sulphur sponge), *Euplectella* (Venus flower basket), *Euspongia* (Bath sponge), etc.

PHYLUM COELENTERATA

(*coel* = cavity; *enter* = intestine; *ata* = group) or **Cnidaria** (Gr. *knide* = stinging cells).

Characters :

1. These have a central cavity called **coelenteron**, also called **gastrovascular cavity**, which helps in digestion and circulation of food.

2. These have **tissue - organisation, blind-sac plan** and are **radially symmetrical.**

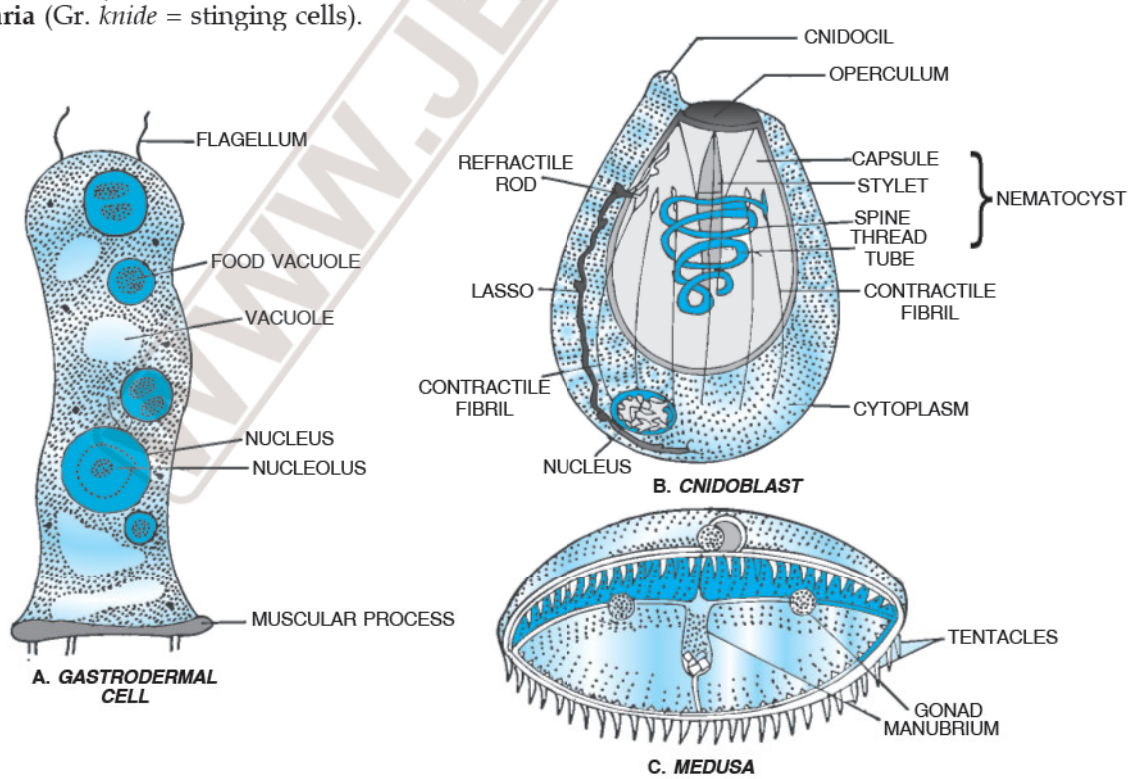

Fig. 8. Important characters of Coelenterata.

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3. These are **diploblastic** animals and body wall in adult coelenterates is formed of two layers—outer **epidermis** and inner **gastrodermis.** Epidermis has peculiar stinging cells called **cnidoblasts** or **nematoblasts** (Fig. 8 B) which inject **hypnotoxin** into prey to paralyse it. Due to presence of cnidoblasts, it is also called **Cnidaria.** Cnidoblasts help in anchorage, defence and food capturing. Between epidermis and gastrodermis, there is a non-cellular gelatinous layer, called **mesoglea.**

4. These are **carnivorous** and **holozoic** in nutrition. Digestion is **partly intercellular** (in coelenteron) and **partly intracellular** (in gastrodermal cells). Coelenteron has single opening **mouth** which helps in both ingestion and egestion.

5. Respiration and **Excretion** occur through general body surface. These are **ammonotelic.**

6. Coelom. These are **acoelomates.**

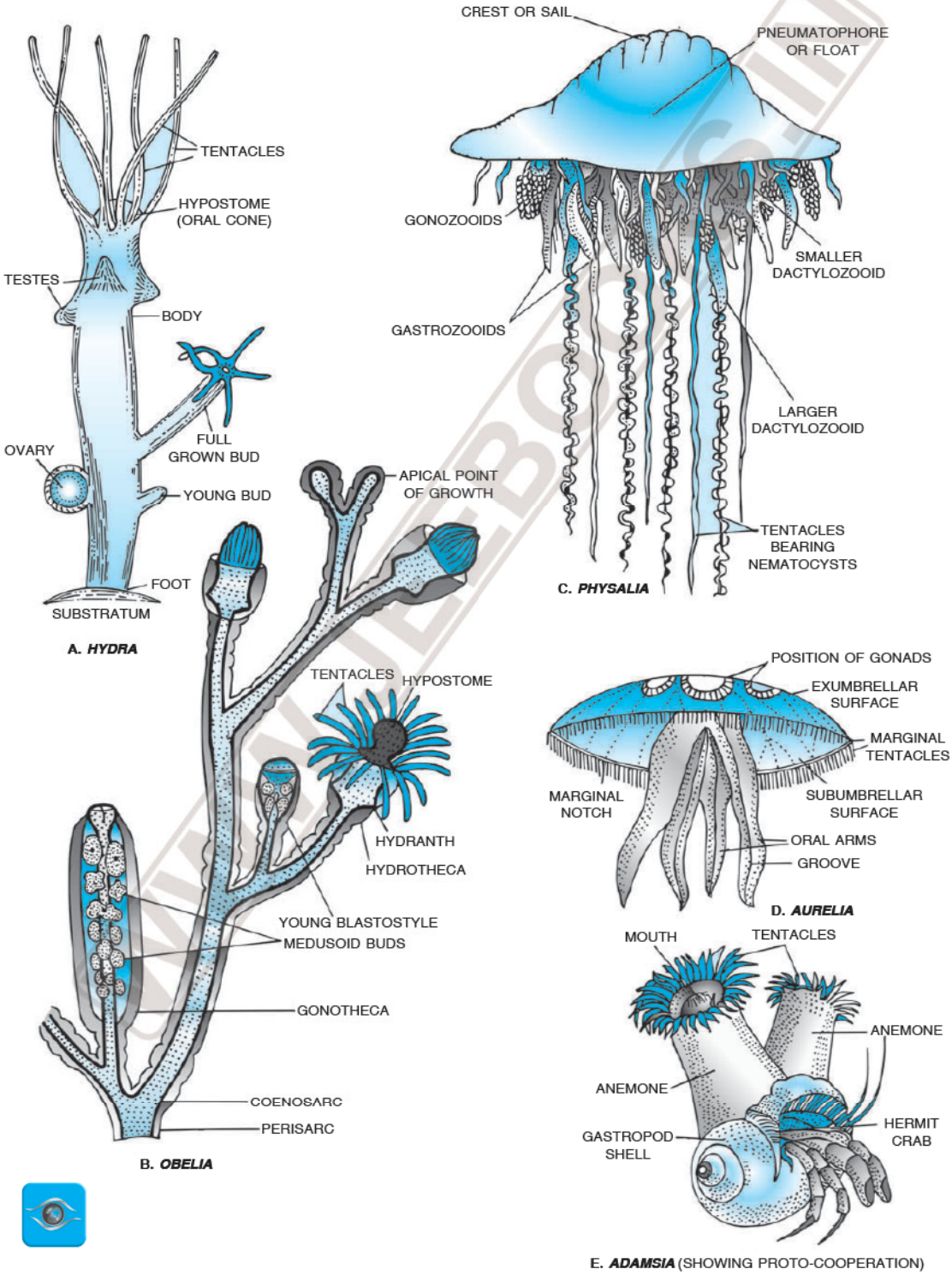

Fig. 9. Important coelenterates.

7. Habitats. All are **marine** except *Hydra.*

8. A few coelenterates are solitary e.g. *Hydra*, **Jelly fish** and **sea anemone**, but most of coelenterates are colonial. Members of colony are called **zooids** which are basically of two types : sessile, flower–like and nutritive **polyp** and solitary, free swimming, saucer-shaped and reproductive **medusa** (Fig. 8 C). Some coelenterates show **polymorphism** *e.g., Physalia, Valella, Porpita*, etc.

9. These have **diffused nervous system.**

10. Reproduction and Development. Coelenterates show asexual reproduction by **budding** and sexual reproduction by **medusae**. Development is generally indirect (except *Hydra*) and includes **planula larva** for dispersal. It shows alternation of generations (**Metagenesis**) in which polyps produce medusae by vegetative budding and medusae form the *Obelia* colony and polyps by sexual reproduction.

There are about **11,000 species** of coelenterates.

CLASSIFICATION FOR COELENTERATA FOR COMPETITIVE EXAMINATIONS

Phylum Coelenterata is divided into **three classes** on the basis of **development of zooids:**

A. Class Hydrozoa (Gr. *hydros* = water; *zoon* = animal). Both medusa and polyp are well developed except *Hydra.* Animals are **radially symmetrical** *e.g. Hydra, Obelia* (**Sea fur**) *Physalia* (**Portuguese-man of war**), *Valella* (**Sail-by-wind**).

B. Class Scyphozoa (Gr. *skyphos* = cup). Medusa is well developed but polypoid phase is reduced; symmetry is **tetramerous radial** *e.g. Aurelia* (**jelly fish**).

C. Class Anthozoa or Actinozoa (Gr. *anthos* = flower). Polypoid phase is well developed while medusa absent. Symmetry is **hexamerous radial** *e.g., Adamsia* (**Sea anemone**), *Fungia* (**mushroom coral**), *Astraea* (**Star coral**), *Pennatula* (**Sea pen**), *Gorgonia* (**Sea fan**), *Madrepora* (**Stag horn coral**).

Examples (Fig. 9) : *Hydra, Porpita, Vallela, Physalia* (Portuguese man-of-war), *Aurelia* (Jelly fish), *Adamsia* (Sea anemone), *Pennatula* (Sea pen), *Gorgonia* (Sea fan), *Meandrina* (Brain coral), *Tubipora* (Organ pipe coral), etc.

PHYLUM CTENOPHORA

(Gr. *ktenos* = comb; *pherein* = bearing)

Characters :

1. These are generally **marine** and **planktonic**.

2. These are **biradially symmetrical** with an oral-aboral axis.

3. These are **diploblastic** animals but mesoglea is with many amoebocytes and smooth muscle fibres and is developed from mesoderm so is called **mesoblast.**

4. These have **tissue level** of organisation.

5. Locomotion is by ciliary movements of 8 vertically arranged **comb plates (Fig. 10)** or **ctenes,** so are commonly called **comb-jellies** or **sea walnuts.**

6. Body appendages. These generally have one pair of long, solid and retractile tentacles which have special adhesive cells, called **colloblasts** or **lasso cells,** but donot have cnidoblasts so is called **Acnidaria**.

7. These are **acoelomates.**

8. These have **complete alimentary canal** and **carnivorous.** Digestion is partly **intercellular** and partly **intra-cellular.** Anus is aboral.

9. Respiration and excretion occur **through body surface.** These are **ammonotelic**.

10. Nervous system. It is of **diffused type.**

11. Bioluminescence (releasing light) is well marked.

12. Peculiar sense organ of ctenophores is **statocyst** which lies in a pit at the aboral pole and helps in **equilibrium.**

13. Asexual reproduction is absent.

14. Sexual reproduction. These are **bisexual** or **hermaphrodite.** Fertilization is external and development includes a ciliated **cydipid larva.**

There are about **100 living species** of Ctenophora.

Examples : *Ctenoplana, Pleurobrachia* (Fig. 10) (sea-gooseberry), **Beroe** *Velanum, Cestum* (Venus's girdle), and *Hormiphora.*

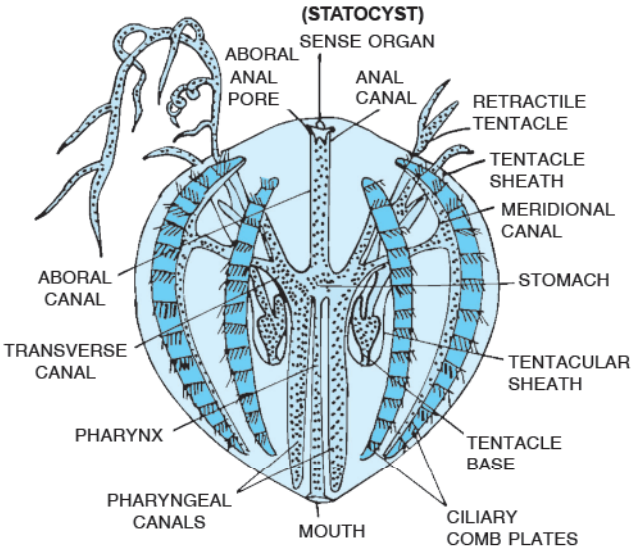

Fig. 10. *Pleurobrachia* (left).

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ADDITIONAL USEFUL INFORMATIONS ABOUT PORIFERA, COELENTERATA AND CTENOPHORA FOR COMPETITIVE EXAMINATIONS

A. PORIFERA (SPONGES) :

- *Porifera is probably oldest animal group including the simplest multicellular animals.*
- *Sponges lack specialised digestive, nervous and circulatory systems.*
- *Sponges are lowest metazoans and are placed in sub-kingdom* ***Parazoa. Parazoology :*** *Scientific study of sponges.*
- *Fossil records show that sponges inhabited around 600 million years ago.*
- *Sponges are* ***master filters****. Some of them can filter an amount of water about 100,000 times their size each day.*
- *Dermal ostia of sponges are analogous to* ***mouths****, while osculum is analogous to* ***anus****.*
- *Mesoglea of sponges is also called* ***mesenchyme*** *or* ***mesophyl****.*
- ***Amoebocytes found in the mesoglea of sponges:***
  - ***Chromocytes :*** *Pigment cells, give colour to the sponges.*
  - ***Trophocytes :*** *Digest the food.*
  - ***Thesocytes :*** *Store the food as glycogen or fats.*
  - ***Collencytes :*** *Secrete collagen fibres.*
  - ***Myocytes :*** *Contractile cells, form sphincters around the apertures like osculum, dermal ostia etc.*
  - ***Phagocytes :*** *Engulf excreta and damaged cells.*
  - ***Sclerocytes :*** *Spicule forming cells.*
  - ***Archaeocytes :*** *Totipotent cells for regeneration and reproduction.*
- ***Gemmule :*** *An internal bud of Spongilla (a fresh-water sponge). It is fromed of a mass of archaeocytes surrounded by a coat of amphidisk spicules. It helps in perennation. These act as spores of sponges while their formation is called* ***Gemmation.*** *Gemmules are also found in some marine sponges e.g.* ***Ficulina, Tethya,*** *etc.*
- *In the cavity of Euplectella, a pair of crustacean -* ***Venusta spongicola*** *lives till death.*
- ***Scypha (Sycon) :*** *Shows cross fertilization due to* ***protogynous*** *condition. Development includes* ***amphiblastula*** *larva.*
- ***Euplectella :*** *Its dried skeleton is used as* ***marriage gift*** *in Japan as a symbol of "****Union till death****".*
- ***Spongilla :*** *It is the* ***only fresh-water sponge.*** *It reproduces asexually by* ***gemmulation.***
- ***Hyalonema (Glass rope sponge) :*** *It is fixed in the mud by a root tuft of twisted spicules.*
- ***Cliona (Boring*** *or* ***Sulphur sponge) :*** *Its larva bores through and damages the skeleton of corals and shells of mollusks. It is harmful to pearl industry.*
- ***Chalina (Dead man's finger sponge) :*** *Sponge is branched and branches give the appearance of a hand with many fingers.*
- ***Proterospongia :*** *With both amoeboid and collar cells so acts as a* ***connecting link*** *between Protozoa and Porifera.*
- ***Hippospongia*** *is a* ***horse sponge****, whole Halichondria is called* ***crumb of bread sponge.***
- ***Phyllospongia*** *is* ***leaf sponge,*** *while* ***Pheronema*** *is called* ***bowl sponge.***
- ***Luffa sponge:*** *It is not a sponge but is dried and fibrous skeleton of gourd.*
- ***Euspongia (Bath sponges):*** *Its skeleton is formed of only spongin fibres. Its dried skeleton is used for bathing, washing, etc.*
- ***Leucosolenia :*** *Simplest sponge with* ***asconoid type canal system*** *and has* ***parenchymula*** *and* ***stereogastrula*** *(solid gastrula) larval stages.*
- ***Oscarella*** *is the sponge with no skeleton.*
- ***Asconoid canal system*** *is found in* ***Leucosolenia, Syconoid C. S.*** *is found in Sycon and* ***Grantia*** *while* ***Leuconoid C. S.*** *is found in* ***Euspongia, Spongilla****, etc.*
- *Larval form of members of class Demospongiae is* ***rhagon larva****.*

B. COELENTERATA :

- *Coelenterates are simplest, invertebrate animals with simple living tissues.*
- *Coelenterates are commonly called* ***cnidarians*** *due to presence of cnidoblasts, so study of coelentrates is called* ***cnidology.***
- ***Trambly*** *(1744): First to report regeneration in Hydra.*
- *Ceolenterates cannot digest starch as have* ***no amylase*** *enzyme.*
- *In coelenterates,* ***interstitial cells*** *act as totipotent cells.*
- ***Nerve cells*** *appeared first of all in coelenterates and are non-polarized.*
- *Germ cells are ectodermal in origin in Hydrozoans, while are endodermal in origin in Scyphozoans and Anthozoans.*
- *Stimulus for discharge of cnidoblasts is partly mechanical (i.e. weight or touch of the prey) and partly chemical (presence of* ***glutathione*** *in the prey).*
- ***Metagenesis :*** *Alternation between asexual and sexual generations in coelenterates, both bing diploid.*
- ***Statocyst*** *(a sense organ for balance) is developed for first time in Cnidaria.*
- ***Hydra : Only fresh-water coelenterate.*** *It has no medusoid stage and planula larva in the life cycle.*
- ***H. oligactis*** *is brown coloured (due to symbiotic brown alga* ***Zooxanthellae*** *in gastrodermal cells), while* ***H. viridissima*** *is green coloured (due to symbiotic green alga* ***Zoochlorella*** *in gastrodermal cells).* ***H. vulgaris*** *is pale in colour.*
- ***Obelia (Fig. 9B) : Seafur,*** *a marine, sedentary and* ***trimorphic*** *colonial coelenterate. It has 3 types of zooids : nutritive and flower-like* ***polyp*** *enclosed in a* ***hydrotheca;*** *long and cylindrical mouthless* ***blastostyle*** *enclosed in a* ***gonotheca****; and umbrella-like* ***medusa*** *with gonads and developed as a bud on the blastostyle. It is commonly called* ***zoophyte*** *due to its plant like appearance.*
- ***Physalia*** *is a polymorphic coelenterate and bears* ***dactylozooids*** *(for defence),* ***gastrozooids*** *(for food capturing),* ***gonozooids*** *(bear medusae) and* ***gonophores*** *(bear gonads). It shows* ***proto-cooperation*** *with* ***Nomeus*** *fish. It is commonly called* ***Portuguese-man-of war*** *due to its sudden appearance. It secretes* ***neurotoxin*** *in sea water so is nuisance to the bathers.*

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- *Aurelia* (*Jelly fish* or *Moon jelly*) involves internal and cross-fertilization. Life cycle involves the formation of **Planula** larva, **Scyphistoma** larva (a reduced polyp) and **Ephyra** larva which undergoes metamorphosis.
- *Adamsia* (*Sea anemone*) shows **proto-cooperation** with **Eupagurus** (Hermit-crab-a crustacean).
- *Corallium rubrum* : Also called **red coral (moonga)** and is used in jewellery; while **Meandrina** is commonly called **brain coral** as has convolutions like human brain.
- *Alcyonium* : Commonly called **Dead man's finger coral** or **soft coral** as zooids are embedded in a gelatinous mesoglea called **coenenchyme.**
- *Gorgonia* is commonly called **sea fan** or **horny coral** (as skeleton is formed of horny **gorgonin** protein).
- *Millipora* is called **stinging coral,** and **Madrepora** or **Acropora** is commonly called **stag-horn coral.**
- *Corals* are skeleton secreting anthozoans, while **sea-anemones** are anthozoans with no skeleton.
- *Corallite* is individual calcareous skeleton of a coral coelenterate while **coenosteum** is colonial calcareous skeleton formed by fusion of corallites.
- *Coral reefs* : A coral reef is a ridge in the sea and is formed of skeletons of the coelenterates called **corals.** It is mainly formed of skeletons of stony corals like Madrepora but is impregnated by skeletons of Millipora and Tubipora. It is mainly formed of calcium carbonate. Coral reefs form stable marine ecosystems. These are of 3 **types** (by **Hyman,** 1940) :
  - ☞ **Fringing reefs.** These extend from the shore upto a distance of 400 metres into the sea.
  - ☞ **Barrier reefs.** These run parallel to the shore but are separated from shore by a water body called **lagoon.** Largest barrier reef is **Great Barrier Reef** in the north-east coast of Australia and is 1920 km long.
  - ☞ **Atoll.** It is circular coral reef surrounding a quiet water body called **lagoon.** It is also called **coral island.**

  In India, **Lakshadweep islands** are formed of coral islands. Fiji and Maldive islands are also coral islands.
  These are mainly found in warm (70°F) and shallow waters of tropical seas. The pacific north-east of Australia is called **coral sea.**

C. CTENOPHORA

- Phylum Ctenophora is also called **Acnidaria** as these lack cnidoblasts.
- Mesoglea of ctenophores is of **collenchymal nature** (with many cells).
- **Differences between Coelenterates and Ctenophores**
  - ☞ Coelenterates are more diversified in terms of number of species.
  - ☞ Coelenterates are mostly marine, while ctenophores are exclusively marine.
  - ☞ Coelenterates are radially symmetrical while ctenophores are biradially symmetrical.
  - ☞ Cnidoblasts present only in the coelenterates, while ctenophores have colloblasts to capture prey.
  - ☞ Digestive tract is complete in ctenophores but is incomplete in the coelenterates.
  - ☞ Comb plates present in only ctenophores but are absent from the coelenterates.

PHYLUM PLATYHELMINTHES

(Gr. *platys* = flat; *helmins* = worms) **(FLAT WORMS)**

Characters :

1. Body is either leaf-like or ribbon-like **dorsoventrally flat.** It lacks true segments. These are soft-bodied.

2. These are **first animals** to have **organ-level organisation** and **bilateral symmetry.** These have **blind sac** body plan.

3. These are **triploblastic** and **acoelomate** animals.

4. Spaces between the body organs are filled with a mesodermal connective tissue, called **parenchyma.**

5. Habitat. These are **mostly parasitic** but some are free living (e.g. planarians). Parasitic forms have hooks and suckers for adhesion on their host.

6. Excretion and osmoregulation occur by peculiar cells called **flame cells** or **protonephridia or solenocytes** (Fig. 11 A). These are **ammonotelic.**

7. Gut. These have **incomplete alimentary canal.** It is absent in tape worms.

8. Nervous system. It is **ladder-like** (Fig. 11B).

9. These are **first animals** to show **cephalization.**

10. Reproduction. These are **mostly hermaphrodite.** Fertilization is internal and may be self or cross-fertilization. Development includes larval stages so is **indirect**. Turbellarians undergo asexual reproduction by **transverse fission.**

11. Planarians have very high power of **morpholactic regeneration.**

There are about **25,000 species of** flatworms.

CLASSIFICATION OF PLATYHELMINTHES FOR COMPETITIVE EXAMINATIONS

It is divided in **three classes** on the basis of **body shape, mouth position and habitat.**

A. Class Turbellaria (L. *turbella* = stirring). (i) Body is **leaf-like** and unsegmented. (ii) Mouth is present on **ventral side** of middle of body and pharynx is protrusible. (iii) These are free-living. (iv) Body is externally covered by a **ciliated epidermis** but there is no cuticle.

These are commonly called **planarians** *e.g. Planaria, Dugesia.*

B. Class Trematoda (Gr. *trema.* = hole; *eidos* = form). (i) Body is **leaf-like** and unsegmented. (ii) Mouth is present on **anterior end** of body. (iii) These are either **ecto- or endoparasites.** (iv) Body is externally covered with a living **tegument** produced into spinnules.

These are commonly called **flukes** *e.g., Fasciola* **(Sheep liver-fluke)**, *Schistosoma* **(blood fluke)**, etc.

C. Class Cestoda (Gr. *kestos* = girdle; *eidos* = form). (i) Body is **ribbon-like** and divided into segments called **proglottids.** (ii) Mouth and **alimentation absent** so absorb the nutrients through their body surface. (iii) These are **only endoparasites.** (iv) Body is externally covered with a living **tegument** but with no spines.

These are commonly called **tapeworms** *e.g., Taenia solium* **(Pork tapeworm)** and *T. saginata* **(Beef tapeworm).**

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Parasitic adaptations in Flukes and Tapeworms:

1. Absence of epidermis and presence of tough and resistant horny **cuticle** on the body wall.

2. The **sense organs** like **eye-spots** are either reduced or absent.

3. These have some **adhesive structures** like suckers or hooks or both or other structures.

4. One or more **intermediate hosts** in the life history to reduce their period of exposure.

5. Absence of **organs of locomotion.**

6. Alimentation absent in tapeworms.

Examples (Fig. 12) : *Taenia* (Tapeworm), *Fasciola* (Liver fluke), *Echinococcus* (Dog tapeworm) and *Planaria.*

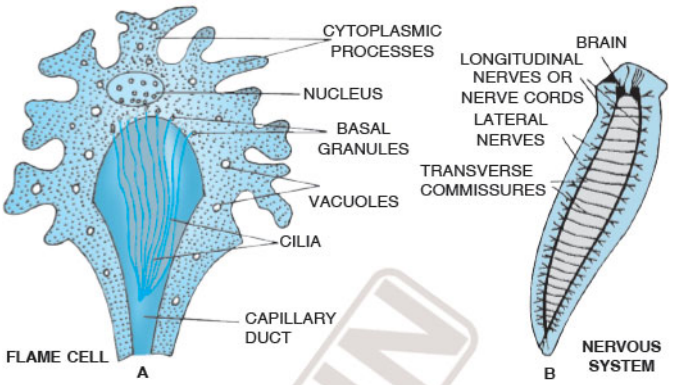

Fig. 11. Important characters of Platyhelminthes.

Table 10. Differences between Planarians, Flukes and Tapeworms.

Characters	Planarians	Flukes	Tapeworms
1. Body form	Leaf-like and unsegmented.	Leaf-like and unsegmented.	Ribbon-like and segmented.
2. Position of mouth	On middle of ventral side of body.	On ventral side of anterior end of body.	Absent.
3. Mode of living	Free-living.	Ectoparasitic or endoparasitic.	Always endoparasitic.
4. Body covering	Ciliated epidermis.	Spiny cuticle.	Non-spiny cuticle.
5. Examples	*Planaria, Dugesia,* etc.	*Fasciola, Schistosoma,* etc.	*Taenia, Hymenolepis,* etc.

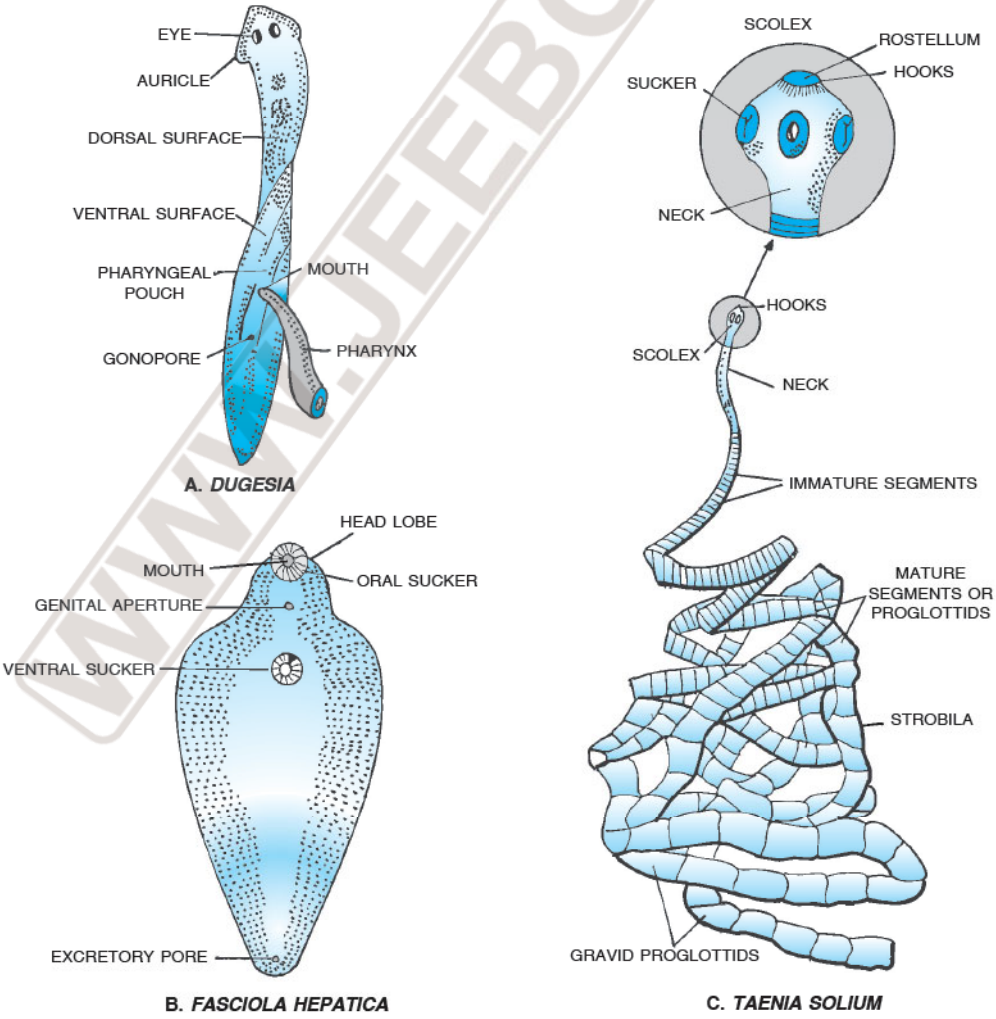

Fig. 12. Important Flatworms.

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ADDITIONAL USEFUL INFORMATIONS ABOUT PLATYHELMINTHES FOR COMPETITIVE EXAMINATIONS

- *Term platyhelminthes was given by* ***Gegenbaur*** *(1859).*
- *Around 80 per cent of the flatworms are parasitic in nature.*
- *Alimentation is altogether absent from any stage of the tapeworms.*
- ***Turbellarians (Planarians) :***
  - ***Dugesia*** *is with a triangular head with two auricles, while* ***Planaria*** *is with a truncated head.*
  - *Like Hydra, Planaria also has* ***morpholactic regeneration.***
  - ***Bipalium :*** *Only terrestrial planarian.*
  - ***Morpholactic regeneration :*** *One part of body can form the whole body.*
- ***Trematodes (Flukes) :***
  - ***Fasciola hepatica :*** *Sheep liver fluke–an endoparasite of bile duct of sheep. Its life cycle is* ***digenetic*** *(sheep and snail), complex and shows* ***poly-embryony*** *(a number of larval stages like miracidium, sporocyst, redia, cercaria and metacercaria are formed). Its heavy infection causes* ***liver rot*** *disease in sheep.*
  - ***Schistosoma (Blood-fluke).*** *It is the* ***only unisexual fluke*** *found in the veins of man. Female is present in the* ***onchosphere gynaecophoral canal*** *(a groove on ventral side) of male. It causes* ***schistosomiasis*** *characterized by intestinal disorders. It is also called* ***Bilharzia.***
  - ***Opisthorchis sinensis :*** *Chinese liver fluke of man.*
  - ***Paragonimus :*** *Lung fluke of man.*
  - ***Monogenetic flukes :*** *With monogenetic life cycle e.g.* ***Diplozoan*** *(ectoparasite of gills of fishes),* ***Gyrodactylus.***
  - ***Digenetic flukes :*** *With two hosts in life cycle e.g.* ***Fasciola, Schistosoma,*** *etc.*
  - ***Prohaptor :*** *Anterior sucker of flukes.*
  - ***Opisthaptor :*** *Posterior sucker of flukes.*
- ***Cestodes (Tapeworms) :***
- ***Taenia solium (Pork Tapeworm) :*** *It is* ***digenetic*** *(man and pig) and* ***hermaphrodic*** *tapeworm. Development includes* ***onchosphere hexacanth*** *and* ***cysticercus*** *larvae. Worm causes* ***taeniasis*** *disease while larvae cause* ***cysticercosis*** *disease.*
  - ***Taenia saginata (Beef-tapeworm).*** *It is found in small intestine of man. Secondary host is* ***cow.*** *Human infection is by taking undercooked measly beef. Its scolex is without hooks and rostellum while strobila is formed of about 2,000 proglottids.*
  - ***Apolysis :*** *Loss of gravid proglottids from posterior end of body.*
  - ***Strobilation :*** *Formation of new proglottids from neck, also called* ***pseudometamerism.***
- ***Diphyllobothrium :*** *Largest tepeworm (18 m.)*
- ***Hymemolepis :*** *Dwarf tapeworm (2–4.5 cm). It is monogenetic tapeworm of man.*
- ***Echinococcus*** *is also called* ***dog tape worm.***
- *World population suffers more from Taenia saginata than T. solium due to more beef eaters.*

PHYLUM NEMATHELMINTHES OR ASCHELMINTHES

(Gr. *nema* = thread; *helmins* = worms)

(**Thread** or **roundworms**)

Characters :

1. Body form. These are commonly called **roundworms** or **threadworms** or **bagworms** (*askos* = bag) because the body is long, cylindrical, vermiform, unsegmented, thread-like with no lateral appendages. So their cross section is always circular.

2. These have **organ-system organization** and **bilateral symmetry.**

3. These are **triploblastic animals** (Mesoderm is present as scattered pouches between ectoderm and endoderm).

4. These are either free-living or parasitic. Free living round worms are extremely abundant in soils.

5. These are **pseudocoelomates.**

6. These are **first animals** to have straight and **complete alimentary canal.** Pharynx is muscular and tri-radiate. Intestine is non-muscular. So these have **tube-within-a-tube plan.**

7. Excretion. Excretory system is **H-shaped** and **intracellular** called **Rennett cell.** These are **ammonotelic.**

8. Body wall is formed of outer non-living **cuticle of keratin (a scleroprotein), syncitial (multinucleate) epidermis** and only **longitudinal muscle fibres.** Circular muscles are absent.

9. Number of cells is fixed in every system of body **(Eutyly).** These show **auxetic growth.**

10. Nervous system. It is formed of a **circumpharyngeal nerve ring** giving rise to anterior as well as posterior nerves interconnected by connectives. So it is of **ladder type.**

Table 11. Differences between Flatworms and Round worms.

Characters	Flatworms	Round worms
1. Body form	Dorsoventrally flattened.	Long and cylindrical.
2. Body cavity	Acoelomates.	Pseudocoelomates.
3. Alimentary canal	Absent or incomplete.	Complete.
4. Excretory structures	Flame cell.	Rennet cell.
5. Epidermis	Non-syncitial and unilaminar or absent.	Syncitial epidermis.
6. Sexes	Generally bisexual.	Always unisexual.
7. Examples	*Planaria, Fasciola, Taenia,* etc.	*Ascaris, Wuchereria, Ancylostoma,* etc.

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SUPPLEMENT YOUR KNOWLEDGE

- Sponges are considered as most primitive multicellular animals.
- Canal system is **ascon type** (*e.g., Leucosolenia*) or **sycon type** (*e.g., Scypha*) or **leucon type** (*e.g., Euspongia*).
- Parenchyma of flatworms acts as **hydraulic skeleton** and **circulation**.
- *Ascaris* is an endoparasitic nematode of children. It shows **sexual dimorphism.** Life cycle is **monogenetic.** Its heavy infection causes **ascariasis.** Male Ascaris is smaller in size, has curved posterior end, cloacal aperture (anus in female) and two spicules.
- Male *Ascaris* is **monorchic** (with single set of male reproductive system).
- Female *Ascaris* is **didelphic** (with double set of female reproductive system).
- *Ancylostoma* (commonly called **hook worm**) is endoparasite of duodenum of small intestine of man. Male has a **copulatory bursa** at its posterior end while female has a **caudal spine** at posterior end.
- **Amphids** are olfactory chemoreceptors of nematodes, while **phasmids** are glandulosecretory structures of nematodes.
- Recently discovered new phylum is **Lorcifera**.

11. Sexes are **unisexual** or **dioecious** and always show **sexual-dimorphism.** Male is smaller in size, has penial spicules, and cloacal aperture (anus in female). Fertilisation is internal. Most of nematodes show **indirect development** e.g. **filariform larva** in *Ancylostoma*; **microfilariae** in *Wuchereria*; **rhabditiform larva** in *Ascaris* and *Enterobius*.

It includes about **15,000** living species out of which about 50 species are parasites of man.

Examples (Fig. 13) : *Ascaris*, *Wuchereria* (Filarial worm), *Ancylostoma* (Hook worm), *Enterobius* (Pin worm), etc.

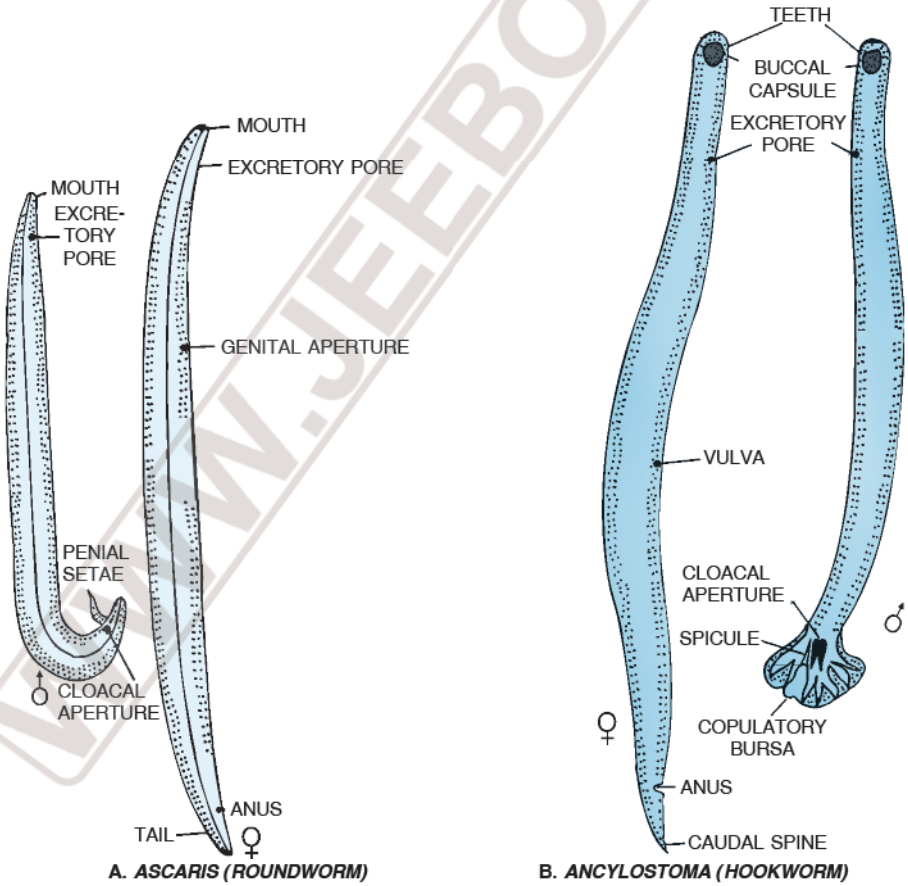

Fig. 13. Important Nematodes.

PRACTICE PROBLEMS – PORIFERA TO ASCHELMINTHES

21. What are choanocytes? Give their function.

22. Why are sponges and coelenterates called diploblastic animals?

23. Name two types of pores on the body of sponges. Give their function.

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24. Name a fresh water sponge and a coelenterate.
25. On which basis, the phylum Porifera is classified?
26. Why is *Euplectella* called venus-flower basket?
27. What are gemmules?
28. Name the sponge having only spongin fibres as its endoskeleton.
29. Why is coelenteron called gastrovascular cavity?
30. What are cnidoblasts? Give their function.
31. Define polymorphism. Name one coelenterate showing polymorphism.
32. Name two basic types of zooids of coelenterates. Give their function.
33. Name three classes of phylum Coelenterata.
34. Why is *Physalia* called Portuguese-man of war?
35. What are coral reefs? Which sea is called coral sea?
36. Give two peculiar characters of phylum Platyhelminthes.
37. Which types of animals are grouped in class Trematoda and Cestoda?
38. Why are *Fasciola* and *Taenia* called digenetic animals?
39. Name three parts of body of *Taenia*. List their function.
40. What is apolysis? Give its significance.
41. List two peculiar characters of phylum Aschelminthes.
42. Give the habitat of *Ascaris*. List two differences between male and female *Ascaris*.
43. Give the scientific name of filarial worm. How is it spread from man to man?

ANSWERS TO PRACTICE PROBLEMS

21. Choanocytes are **collar cells** of sponges. Their flagella beat and maintain a water current.
22. In both of these groups of animals, body is developed from two primary germ layers.
23. (i) **Ostia** are inlets of water current and (ii) **Osculum** acts as outlet of water current.
24. (i) Sponge = *Spongilla*; (ii) Coelenterate = *Hydra*.
25. On the basis of their **endoskeletal** elements.
26. Its dried skeleton is used as a **marriage gift** in Japan and is symbol of **"Union till death".**
27. Gemmules are **internal buds** of *Spongilla*. These help in perennation and multiplication.
28. *Euspongia* (Bath sponge).
29. It is a cavity in which both **digestion and circulation** occur.
30. Also called **stinging cells.** These paralyze the prey as these inject a poisonous chemical called **hypnotoxin.**
31. Polymorphism is presence of many types of zooids (individuals) in a colonial coelenterate e.g. *Physalia*.
32. (i) **Polyp** or Hydranth = Nutrition; (ii) **Medusa** = Reproduction as has gonads.
33. Hydrozoa, Scyphozoa and Anthozoa.
34. Due to its **sudden appearance and disappearance** like navy ships of Portugal.
35. A coral reef is a **mound in the sea** and is formed by skeletons of certain coral coelenterates. The pacific north-east of Australia is called **coral sea.**
36. First animals to be **triploblastic** and **organ-system** organisation. Body is **flat.**
37. (i) Trematoda includes **flukes.** (ii) Cestoda includes **tapeworms.**
38. These complete their life cycle in **two hosts.**
39. (i) **Scolex** = Adhesion to intestine; (ii) **Neck** = Adding new segments; (iii) **Strobila** with 850-1000 proglottids with reproductive organs.
40. Shedding of ripe proglottids from the end of body is **apolysis.** These are eaten by pig which acts as intermediate host.
41. (i) First animals with complete gut (ii) Pseudocoelomates (iii) Fixed number of cells.
42. Found in intestine of children. Male is with curved posterior end and is smaller, while female is straight and longer.
43. *Wuchereria bancrofti*. It is spread by *Culex* mosquitoes.

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ADDITIONAL USEFUL INFORMATIONS ABOUT NEMATHELMINTHES FOR COMPETITIVE EXAMINATIONS

- *Most of nematodes are parasitic. Only few of them are free-living.*
- *Nematode is called* ***monorchic*** *when with one set of male reproductive system, while is called* ***diorchic*** *when with two sets of male reproductive system.*
- *Nematode is* ***monodelphic*** *when with one set of female reproductive system, while is* ***didelphic*** *when with two sets of female reproductive systems.*
- ***Wuchereria bancrofti (Filarial-worm).*** *An* ***endoparasitic, digenetic*** *nematode of lymph vessels of man (primary host) and salivary gland of Culex mosquito (Secondary host). It causes* ***filariasis*** *(also called* ***elephantiasis-swollen legs)*** *in man due to blockage of lymph vessels of legs. Its youngs are called* ***microfilariae*** *which show* ***nocturnal periodicity.***
- ***Enterobius (Oxyuris) - Pinworm.*** *An* ***endoparasite*** *of large intestine of man. It is* ***monogenetic.*** *It causes* ***enterobiasis*** *characterized by sleeplessness, digestive and mental disorders, abdominal pain etc.*
- ***Trichinella (Trichina worm).*** *An intestinal* ***endoparasitic*** *worm of man. Reservoir hosts are pigs, dogs, cats etc. Larvae become spirally coiled in the voluntary muscles. It causes* ***trichinosis*** *characterized by nausea, muscular pain, etc.*
- ***Dracunculus (Guinea worm).*** *An* ***endoparasitic*** *worm of subcutaneus tissue of man. It is* ***digenetic*** *and its secondary host is Cyclops. It causes* ***guinea-worm disease****. It is earliest known nematode and was earlier called.* ***"Fiery Serpent".***
- ***Trichurus (whip worm) :*** *Monogenetic endoparasite of caecum and colon of children. It causes* ***trichuriasis*** *which is characterized by abdominal pain, dysentry and anaemia.*
- ***Ascaris (Additional informations) :***
  - ***Phasmids :*** *Two in number and are chemoreceptor unicellular glands.*
  - ***Amphids :*** *Two in number (one on each ventrolateral lip) and are gustatory.*
  - *Infective stage is encapsulated second juvenile, called* ***rhabditiform larva.***
  - *Life cycle of Ascaris involves* ***four moults :*** *first in the open; second and third moults in lung alveoli, and fourth moult in human intestine.*
- ***Rhabditis and Meloidogyne :*** *Soil nematodes.*
- ***Loa loa*** *(Eye worm) : Adults sometimes pass across the eye ball. Its vector is* ***Tebanus fly.***

PHYLUM ANNELIDA

(L. *annelus* = ring; *eidos* = form) (**Segmented worms**)

Characters :

1. Habitat. These are aquatic or terrestrial, free living or parasitic animals.

2. Body is externally divided into segments called **metameres** or **somites** by ring-like grooves called **annuli,** so called **ringworms** or **segmented worms.**

3. These have **organ-system organization** and **bilateral symmetry.**

4. These are **triploblastic** animals and **first true-coelomate (schizocoelic in origin)** animals. Coelom is with a watery **coelomic fluid** which acts as **hydraulic skeleton** and helps in locomotion.

5. Body wall. It is formed of **cuticle,** single-layered **epidermis** and only smooth muscle fibres (both circular and longitudinal). Cuticle is never moulted.

6. These show **metameric segmentation.**

7. Alimentary canal is **straight and complete** so these have **tube-within-a-tube** body plan. Digestion is entirely **extracellular**.

8. Excretion and **osmoregulation** occur by segmentally arranged and metamerically disposed ectodermal coiled organs, **nephridia.**

9. Nervous system is formed of **circum-pharyngeal nerve ring** and a solid, double, ventral and ganglionated **nerve cord.**

10. These are the first animals to have generally **closed circulatory system.** Colour of blood is **red** due to the presence of **erythrocruorin** in plasma. In leeches, there is no true blood vascular system.

11. These generally show **cutaneous** or **skin respiration** *e.g.*, **earthworm.** Some have **branchial** (gill) respiration (*e.g. Amphitrite*).

12. Organs of locomotion are **setae** *e.g.* earthworm, or unjointed segmental appendages called **parapodia** (*e.g. Nereis*) or **suckers** (*e.g. Leech*)**.** This forms the basis of classification of Annelida.

13. Sexes may be **unisexual** (*e.g., Nereis*) or **bisexual** (*e.g.*, Earthworm, Leech). Fertilization is generally cross and may be **external** (*e.g., Nereis*) or **internal** (*e.g.*, Leech) Development is **direct** in hermaphroditic annelids (Earthworm, Leech) or **indirect** in unisexual annelids (*Nereis*) and includes a free-swimming **trochophore larva.**

Phylum Annelida includes about **17,000 living species.**

Examples (Fig. 14) : *Pheretima* (earthworm), *Tubifex*, *Nereis*, *Aphrodite* (sea mouse), *Chaetopterus* (paddle worm), *Hirudinaria* (leech), etc.

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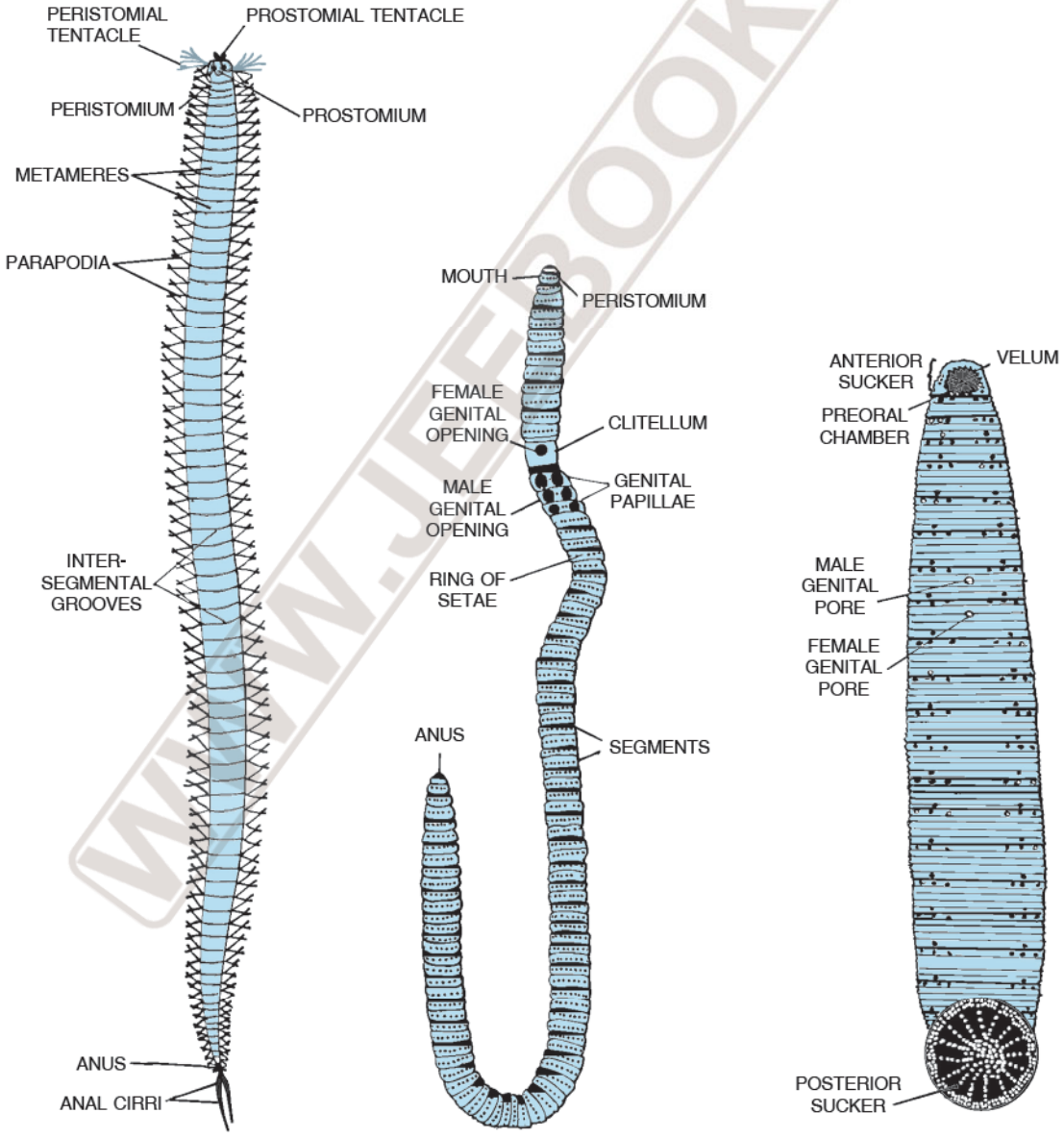
CLASSIFICATION OF ANNELIDA FOR COMPETITIVE EXAMINATIONS

Annelida is divided into **three classes** on the basis of **organs of locomotion:**

Characters	A. Class Oligochaeta (*Gr. oligo* = a few; *chaeta* = hair)	B. Class Polychaeta (*Gr. poly* = many; *chaeta* = hair)	C. Class Hirudinea (*L. hirudo* = leech)
1. Organs of locomotion	A few setae per segment.	Many setae on parapodia, one pair per segment.	Suckers.
2. Clitellum	Permanent clitellum present.	Absent	Clitellum developed in breeding season only.
3. Sexes	Hermaphrodite.	Unisexual.	Hermaphrodite.
4. Development	Direct.	Indirect with trochophore larva.	Direct
5. Examples	*Pheretima posthuma*, *Lumbricus*, *Tubifex* etc.	*Nereis* (**Sand worm**), *Eunice*, *Aphrodite*, etc.	*Hirudinaria* (**Leech**), *Pontobdella*, etc.



A. *NEREIS* (SANDWORM) **B. *PHERETIMA POSTHUMA* (EARTHWORM)** **C. *HIRUDINARIA* (CATTLE LEECH)**

Fig. 14. Some Important Annelids.

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ADDITIONAL USEFUL INFORMATIONS ABOUT ANNELIDA FOR COMPETITIVE EXAMINATIONS

- *Smallest known annelid is Neotenotrocha (less than 1 mm) while largest annelid is* ***Megascolides australis*** *(about 1 meter in length).*
- *Term Annelida was first coined by* ***Lamarck*** *(1809).*
- ***Botryoidal tissue :*** *A special tissue in the leeches which reduces the coelom and is probably excretory in function.*
- *Leeches have* ***open-type haemocoelomic system*** *of longitudinal channels filled with a red-coloured* ***haemocoelomic fluid,*** *while oligochaetes and polychaetes have* ***closed circulatory system.***
- ***Archiannelida*** *includes primitive annelids with no setae and parapodia, faint annuli but complete septa dividing the coelom e.g.* ***Polygordius.***

A. OLIGOCHAETA :

- *Pheretima posthuma -* ***Earthworm :***
  - ***Earthworm*** *is* ***fossorial*** *and* ***hermaphroditic*** *annelid. It feeds mainly on humus. It shows cross fertilization due to* ***protandrous*** *condition. It is commonly called* ***Nature's ploughman.***
  - ***Peristomeum*** *is first segment of earthworm.*
- ***Tubifex (Blood worm) :*** *A darkly red-coloured oligochaete (as with large amount of haemoglobin in blood) so can survive even in a highly O_2 - deficient and polluted fresh-water body. Its presence indicates sewage contamination of water bodies.*
- ***Lumbricus*** *is European earthworm, while* ***Megascolex*** *is South Indian earthworm.*

B. POLYCHAETA :

- *Gonads are* ***temporary structures*** *and developed only during the breeding season.*
- ***Epitoky :*** *Transformation of a non-sexual into a sexual polychaete. Posterior part of body with gonads and parapodia with leafy outgrowths and oar-like setae is called* ***epitoke,*** *while anterior non-modified part is called* ***atoke.***
- ***Aphrodite :*** *Commonly called* ***sea mouse,*** *and while* ***Polynoe*** *is called* ***scale worm.*** *Both show bioluminescence.*
- *In* ***Eunice (Polalo worm),*** *epitoke is regenerated a number of times.*
- ***Chaetopterus (Paddle worm) :*** *A tubiculous, marine polychaete. It has 3 fan-like notopodia in its middle part of body which beat and maintain a water current.*
- ***Nereis*** *has closed circulatory system but* ***no heart.***
- *Reproductive phase of* ***Nereis*** is called ***Heteronereis.*** *Epitoke of* ***Nereis*** *has foliaceous parapodia, oar-like setae and gonads. Development includes* ***Trochophore*** *larva.*

C. HIRUDINEA :

- ***Hirudinaria granulosa (Indian cattle leech) :***
  - ***Crop*** *is largest part of gut. It is 10 chambered and stores the blood.*
  - *Leech has 17 pairs of nephridia and are of 2 types :*
    - *— 11 pairs of* ***testicular nephridia*** *(one pair in each from 12th to 22nd segment).*
    - *— 6 pairs of* ***pre-testicular nephridia*** *(one pair in each of 6th to 11th segment)*
  - ***Ciliated organs*** *of nephridia have no excretory function but manufacture coelomic corpuscles of haemocoelomic system.*
  - *Leech has* ***11 pairs of testis sacs,*** *one pair in each segment from 12th to 22nd segment, but has only* ***one pair of ovaries*** *in 11th segment.*
- ***Pontobdella (Skate sucker)*** *is marine leech and sucks the blood of skatas, rays, sharks.*
- ***Hirudo medicinalis :*** *Medicinal leech of Europe and is a fresh-water leech.*
- ***Phlebotomy :*** *Method of* ***blood-letting*** *to suck the impure blood by applying a lean hungry leech to the skin.*
- *A leech segment with five subsegments is called* ***complete segment*** *or* ***quinquinulate.***
- *All the leeches are* ***sanguivorous*** *and have an anticoagulant called* ***hirudin*** *in their saliva.*

PHYLUM ARTHROPODA

(Gr. *arthros* = joint; *podos* = foot)

(Animals with Jointed feet)

Characters :

1. Arthropoda is **largest phylum** and includes about **80%** (more than two-third) of total animals. It includes **1,134,000 species.**

2. These have **organ - system organization** and **bilateral symmetry.**

3. Germ layers. These are **triploblastic** animals.

4. These are **haemocoelomates** and have a pseudocoel filled with blood and is called **haemocoel.**

5. These have a **sclerotized exoskeleton** which is formed of chitinous cuticular plates called **sclerites.** Exoskeleton undergoes periodic moulting or ecdysis. The exoskeleton of most crustaceans are biomineralised with calcium carbonate extracted from the water.

6. Body division. Body is formed of 2 or 3 parts. When 3 body parts, these are called : **Head**, **thorax** and **abdomen** but when 2 body parts, then called **cephalothorax** (head and thorax fused) and **abdomen** or **head** and **trunk** (thorax and abdomen fused).

7. Mouth is always surrounded by **mouth-parts** which are of different types in different insects *e.g.*, **chewing type** in cockroach, **siphoning** type in butterflies, **sponging** type in house flies, **piercing** and **sucking** type in mosquitoes.

8. These have **jointed appendages** which are differently modified to perform different function *e.g.*, for **pollen-collection** in honey bee; for **jumping** in

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grasshopper; etc. These may be 3 pairs (e.g. in insects) or 4 pairs (e.g. in spiders) or 5 pairs (e.g. decapod crustaceans) or many pairs (e.g. millipedes).

9. Alimentary canal is complete and **coiled.**

10. These are **first animals** to have **voluntary muscles.**

11. Respiration is by either **gills** (*e.g.*, Prawn) or **tracheae** (*e.g.*, Cockroach) or **book gills** (*e.g.*, King crab) or **book lungs** (*e.g.*, Scorpion).

12. Excretion. It is by either **antennary glands** (Prawn) or **Malpighian tubules** (Cockroach) or **coxal glands** (Scorpion). Aquatic forms are **ammonotelic** while terrestrial forms are **uricotelic**.

13. Circulatory system is of **open type.** Blood is colourless and is called **haemolymph** (analogue of blood) because it is without **haemoglobin.** Heart is tubular and lies on dorsal side and has **ostia.**

14. These are **first animals** to have endocrine system. Some insects secrete **pheromones** in air which generally act as **sex-attractant** (e.g. **Bombycol** secreted by female moth) or **alarm signals** or **path indicator**.

15. Nervous system. It is formed of **circum-oesophageal nerve ring** and a double, ventral and ganglionated **nerve cord.**

16. Many arthropods have **compound eyes** (each formed of many **ommatidia**) with **mosaic vision**. Aquatic forms (*e.g.*, Prawn) have **statocysts** as hydrostatic organs. Heads have feelers called **antennae** (one pair in insects, centipedes and millipedes; and two pairs in crustaceans but these are absent in arachnids).

17. Sexes are generally **unisexual** or **dioeceous.** Fertilization may be **external** (in aquatic forms e.g. prawn) but is mostly **internal.** These are generally **oviparous** while only a few are **viviparous** (*e.g.*, Scorpion). Development may be **direct** (Cockroach) or **indirect** (e.g. **caterpillar larva** in butterflies and moths).

CLASSIFICATION OF ARTHROPODA FOR COMPETITIVE EXAMINATIONS

Phylum **Arthropoda** is divided into **seven classes :**

A. Class Onychophora. (i) Body is **worm-like** and segmented. **(ii)** Body segments bear **unjointed legs** with claws. **(iii)** Terrestrial and found in moist habitat. **(iv)** Respiration by **tracheae. (v)** Excretion by **nephridia** *e.g., Peripatus* **(Walking worm**).

B. Class Crustacea. (i) Body is divided into two parts: **cephalothorax** and **abdomen.** Cephalothorax is covered by a shield called **carapace (ii)** Thorax generally bears **5 pairs** of appendages. **(iii) Aquatic** in habitat. **(iv) Branchial** respiration. **(v)** Excretion occurs by **antennary (green) glands. (vi)** These have **two pairs of antennae. (vii)** Exoskeleton is deposited with calcium salts (L. *crusta* = hard shell), *e.g., Palaemon* **(Prawn)**; *Daphnia* **(water flea)**; *Carcinus* or *Paratelphusa* **(crab).**

C. Class Chilopoda. (i) Body is divided into two parts : **head** and **trunk (ii)** Each segment of trunk bears a pair of **jointed legs.** First pair of legs are modified into **poison-claws. (iii) Terrestrial (iv) Tracheal respiration. (v)** Excretion occurs by **Malpighian tubules** *e.g., Scolopendra* **(Centipede** - hundred legger).

D. Class Diplopoda. (i) Body is divided into three parts : **head, thorax** and **abdomen (ii)** Each segment of thorax has 1 pair of jointed legs. Each segment of abdomen has two pairs of legs. There are about 70—100 pairs of legs. **(iii) Terrestrial (iv)** Respiration by **tracheae (v)** Excretion by **Malpighian tubules.** *e.g., Julus* or *Thyroglutus* **(Millipede** - thousand legger).

E. Class Insecta. (i) Body is divided into three parts : **head, thorax** and **abdomen. (ii)** Thorax always has **three pairs of jointed legs** so called **Hexapoda.** Thorax generally has **1** or **2 pairs** of wings. **(iii)** Habitat is **variable. (iv)** Respiration is by **tracheae. (v)** Excretion is by **Malpighian tubules. (vi)** These have **one pair of antennae.**

It is the **largest** class of animals and includes more than **750,000 species** *e.g., Periplaneta* **(Cockroach)**, *Lepisma* **(Silver fish)**, *Microtreme* **(Termite** - white ant), *Apis* **(Honey bee)**, *Pediculus* **(Head louse)**, *Xenopsylla* **(Rat flea)**, *Bombyx mori* **(Silk-moth)**, *Culex/Anopheles* **mosquitoes** etc.

F. Class Arachnida. (i) Body is divided into two parts : **cephalothorax** and **abdomen. (ii)** Cephalothorax has **4** pairs of **walking legs,** one pair of forcep-like **chelicerae** for capturing prey and one pair of **pedipalpi** for reproduction. **(iii)** Respiration is by **tracheae** or **book-lungs. (iv)** Excretion is by **coxal glands** or **Malpighian tubules. (v)** These have no antennae. *e.g., Palamnaeus* or *Buthus* **(Scorpion)**, *Aranea* **(Spider)**, *Sarcoptes* **(Itch mite)**, *Boophilus* **(Cattle tick)**.

G. Class Merostomata. (i) Body is divided into two parts : **Cephalothorax** and **abdomen. (ii)** Cephalothorax bears one pair of **chelicerae** and 5 pairs of **walking legs. (iii)** Respiration occurs by **book gills. (iv)** Excretion is by **coxal glands (v)** No antennae. *e.g., Limulus* **(King crab** or **Horse-shoe crab)**.

Examples (Fig. 15) : *Cancer* (common crab), *Palaemon* (Prawn), *Balanus* (barnacle), *Lepisma* (silver fish), *Periplaneta* (cockroach), *Apis* (Honey bee), *Anopheles* (Mosquito), *Musca* (Housefly), *Charaxes* (Butterfly), *Attelabus* (Beetle), *Locusta* (Locust), *Anax* or *Sympetrum* (Dragonfly), *Araneus* (Garden spider), *Limulus* (King crab), *Buthus* (Scorpion), *Scolopendra* (Centipede), etc.

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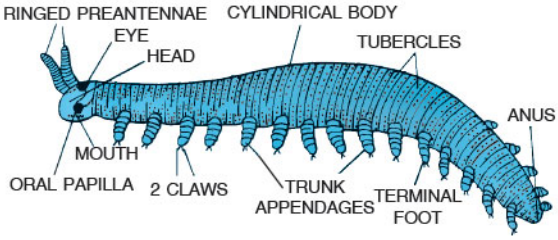
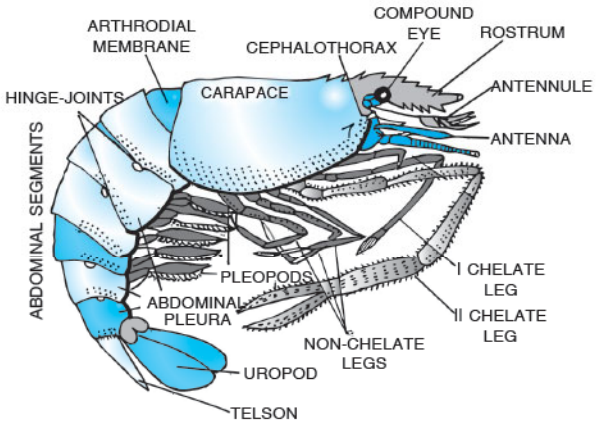
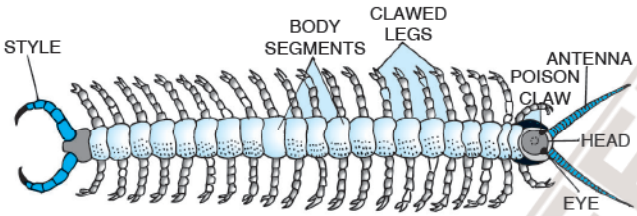


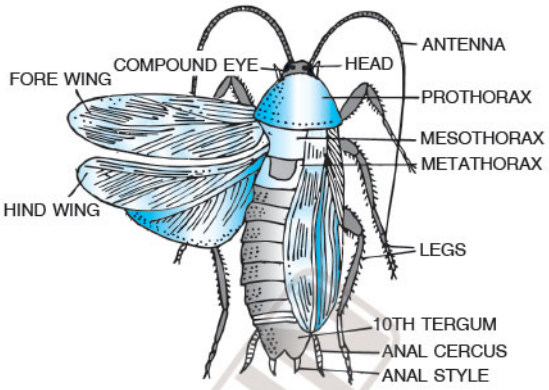
A. *PERIPATUS*—WALKING WORM



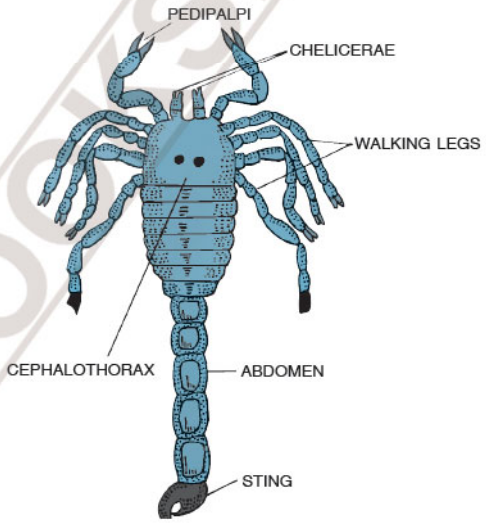
B. *PALAEMON*—PRAWN (MALE)



C. *SCOLOPENDRA* — CENTIPEDE.



D. *PERIPLANETA AMERICANA*—MALE COCKROACH



E. *PALAMNAEUS* (SCORPION)

Fig. 15. A. *Peripatus*; **B.** *Palaemon*; **C.** *Scolopendra*; **D.** *Periplaneta*; **E.** *Palamnaeus.*

Table 12. Differences between Chilopoda and Diplopoda.

Character	Chilopoda (Centipedes)	Diplopoda (Millipedes)
1. **Body division**	Two body parts : **head** and **trunk.**	Three body parts: **head, thorax** and **abdomen.**
2. **Legs**	One pair per segment.	One pair per thoracic segment while two pairs of legs per abdominal segment.
3. **Poison claws**	Present (First pair of legs).	Absent.
4. **Gonopores**	Single and posterior.	Double and anterior.
5. **Gonopods**	Absent.	Present in males.
6. **Stink glands**	Absent.	Present.
7. **Feeding**	Carnivorous.	Herbivorous and saprozoic.
8. **Locomotion**	Runs swiftly.	Walks slowly.
9. **Rolling**	Do not roll into a spiral when disturbed.	Roll into a spiral when disturbed.
10. **Example**	*e.g.*, **Centipede.**	*e.g.*, **Millipede.**

Table 13. Differences between Spider and Insect.

Characters	Spider	Insect
1. **Body division**	Two parts : cephalothorax and abdomen.	Three parts : head, thorax and abdomen.
2. **Mouth parts**	Have **chelicerae** and **pedipalpi.**	Have labrum, labium maxillae and **mandibles.**
3. **Wings**	Absent.	Generally present.
4. **Number of legs**	Four pairs.	Three pairs.
5. **Antennae**	Absent.	One pair of antennae present.
6. **Spinnerets**	Present on abdomen and used to form spider web.	Absent.

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ADDITIONAL USEFUL INFORMATIONS ABOUT ARTHROPODA FOR COMPETITIVE EXAMINATIONS

- *Term Arthropoda was coined by **Von Siebold.***
- *Arthropods have externally-segmented body.*
- ***Trilobites** are fossil arthropods of Cambrian and Permian periods, about 600 million years old e.g. **Dalmanites.***
- *In arthropods, true coelom is restricted to the gonads.*
- ***Parthenogenesis :** Development of egg into adult organism without fertilization e.g. **drones of honey bee, aphids**, etc.*
- ***Coleoptera** is the largest order of animal kingdom and includes beetles.*
- ***Peripatus** is a **viviparous** arthropod. It acts as **connecting link** between Annelida (segmented body, nephridia and unjointed legs) and Arthropoda (Tracheae, haemocoel and heart with ostia).*
- *The rigid cuticle inhibits growth, so arthropods replace it periodically by **moulting**.*
- *Most of arthropods have cuticular bristles, called **setae**, which are often used as sensors to detect air or water currents.*
- ***CLASS CRUSTACEA :***
  - ***Daphnia :** Commonly called **water flea.** Body is covered by a **bivalved carapace.** It shows **cyclomorphosis** (Morphological changes with change of season).*
  - ***Cyclops :** Commonly called **one-eyed monster** (with simple median eye). Female is with **ovisacs** and carries the eggs.*
  - ***Barnacles** are sedentary crustaceans e.g.*
    - ***Lepas :** Called **Ship** or **goose barnacle.** A pedunculate crustacean. Carapace is with 5 calcareous plates.*
    - ***Balanus :** Called **Acorn** or **rock barnacle.** A sessile crustacean. Carapace is with 5 calcareous plates.*
    - ***Sacculina :** Called **root-headed barnacle.** An ectoparasite of crab and highly degenerated crustacean due to retrogressive metamorphosis. Induces the development of female characters in infested male crab, called **parasitic castration.***
  - ***Eupagurus (Hermit crab) :** Shows proto-cooperation with sea anemone (Adamsia).*
  - ***Palaemon (Prawn) :***
    - *Second chelate leg is very large sized in male prawn.*
    - *Prawn shows **autotomy** (can break its legs in self defence) and **regeneration**.*
    - *It swims with **pleopods** of abdomen and shows backward darting with its **tail fin**.*
    - ***P. carcinus** is giant prawn (90 cm), while **P. lamarrei** is dwarf prawn (2.5-5 cm).*
    - *digestive gland of crustaceans is **hepatopancreas** which combines the functions of liver, intestine and pancreas.*
    - ***Prawn fishery :** Capturing of prawns from natural resources as well as their culture. Prawn is rich source of proteins and A and D vitamins but have low fats. **Penaeus indicus** (about 23 cm. long) is most important commercial prawn species in India.*
    - ***Lobster tail :** Abdominal region of spiny lobsters and are used as food.*
  - ***Oniscus :** Only terrestrial crustacean.*
  - *In crabs, abdomen is flexed below cephalothorax and first pair of legs are very large sized, called **chelipeds**, to capture the food.*
- ***CLASS INSECTA :***
  - ***Lepisma (Silver fish)** is a wingless insect and shows no metamorphosis (**Ametaboly**).*
  - ***Cimex lectularis (Bed bug).** It is **ectoparasite** of man, **nocturnal** in activity, **sanguivorous** (piercing-sucking mouth parts)*
  - ***Pediculus (Head louse).** An **ectoparasite** of man; found glued to the body hair, **sanguivorous** in feeding with piercing - sucking type mouth parts; spreads typhus fever.*
  - ***Microtreme (Termite** or **white ant).** A colonial, **polymorphic and social insect,** found in nests called **termitaria** in woods, 5 castes in the colony **(queen, drone, worker, soldiers** and **nasutes);** shows symbiosis with multiflagellate protozoan — **Trichonympha.***
  - ***Poecilocerus pictus (Ak Grasshopper).** It is diurnal, **herbivorous** (on Ak leaves by **chewing-type mouth parts),** and flying and jumping (with large sized **saltatorial metalegs).** Female has **ovipositor** (egg-laying apparatus).*
  - ***Sympetrum or Anax (Dragon fly).** It is diurnal, good flier and **carnivorous** (Flies and mosquitoes) insect. Development includes an aquatic larva called **naiad** and incomplete metamorphosis. Each forewing has a black spot called **pterostigma.** It is also called **mosquito hawk.** It helps in controlling malaria.*
  - ***Musca domestica (Housefly).** It feeds upon the liquid foods **(saprophagous)** with its **sponging type mouth parts** having a fleshy **proboscis.** Hindwings are reduced and are called **halteres.** These act as **balancers.** Development includes **legless maggot** larva and complete metamorphosis. Mandibles are absent.*
  - ***Aphis brassicae (Aphid).** It is a serious plant pest of mustard. It sucks the plant sap with its **piercing and sucking** type mouth parts. The female is **viviparous** and reproduces by **parthenogenesis.** Also called **ant cows** as secrete **honey dew** which is eaten by ants.*
  - ***Moths** are nocturnal and have feathery antennae, while **butterflies** are diurnal and have knobbed antennae.*
  - ***Caterpillar** is the larval stage of moths and butterflies. It has true legs on thorax and pseudolegs on abdomen.*
  - ***Butterfly museum** in India is at Shillong.*
  - ***Bombyx mori (Silkmoth) :** A single cocoon of silk worm provides about 300 metres of silk thread. Rearing of silk-worms on mulberry plants is **sericulture.** Pupa is also called **chrysalis.** India is **second** in the world in production of mulberry silk. **Central Silk Research Institute** is located at **Mysore** (Karnataka).*
  - ***Apis (Honey bee) :** It is a **colonial, polymorphic** and **social** insect. Sexes take **nuptial** or **marriage flight** to mate in air. **Drones** or males are haploid as are parthenogenetically developed, while Queen and workers are diploids. Honey bees produce wax and honey. These help also in pollination. Mouth parts are **chewing and lapping type** adapted to suck nectar and to mould wax. Prolegs of worker bee with **pollen brush,** mesolegs have **pollen spur** while metalegs have **pollen comb, pollen packer***

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*and **pollen basket.** Domestication of honey bee is called **apiculture** while boxes used are called **apiary.** Domesticated spp. include. **A. indica** (mainly used), **A. dorsata, A. florea** and **A. mellifera.** In scoutbees, **waggle dance** was first reported by **Karl von Friesch** (1956). Workers are divided into three categories : **Scavengers** (clean the comb); **Nursing bees** (secrete royal jelly from their maxillary glands and secrete wax from their wax glands) and **Foraging** or **scout bees** (explore new sources of food). Bee dances are of two types : **Round dance** (indicates food source at less than 75 metres) and **Tail wagging dance** (indicates food source at long distance).*

- ☞ ***Mantis religiosa (Preying mantis) :** Carnivorous insect and captures the prey with the help of its **raptorial prolegs.***
- ☞ ***Phyllium (leaf insect)** and **Carausius (Stick insect)** show **mimicry** as body shape is changed as a leaf and a dry stick respectively.*
- ☞ ***Cicada (Seventeen-year locust) :** With **opisthognathous** (backward directed head). Metamorphosis period extends upto about 17 years.*
- ☞ ***Xenopsylla (Rat flea) :** It is ectoparasite of rats, wingless, sanguivorous and has piercing and sucking type mouth parts. It spreads bacteria of plague.*
- ☞ ***Beetles :** Forewings are completely thick and called **elytra** while hindwings are membranous for flight. Larva is with only true legs and is called **grub** e.g. **Coccinella** (Lady bird beetle), **Scarabaeus** (dung beetle), **Sitophilus** (rice weevil — weevil is a grain beetle).*
- ☞ ***Hemielytra :** Half thick and half thin forewings found in bugs.*
- ☞ ***Lac** and **shellac** are provided by **Lac-insect** (**Laccifera** or **Tarchardia**). Lac is secretion of lac insect.*
- ☞ ***Culex mosquito :** Adult keeps body parallel to the surface at rest and wings have no dark spots, while in **Anopheles mosquito,** adult keeps the body inclined to the surface and wings have dark spots. **Wriggler** is larva of mosquito. Their saliva contains an **anticoagulant.** Female Anopheles is sanguivorous while male Anopheles feeds upon plant juices so the mandibles are absent. Hind wings act as halteres or balancers while their hearing organ is **Johnston's organ** present on antenna.*
- ☞ ***Cochineal bug** feeds upon cacti plants so helps in **biological control.** Their dead and dried bodies provide cochineal dye.*
- ☞ ***Vector insects** are those which spread the pathogenic microbes e.g. **Anopheles, Culex** and **Aedes** mosquitoes.*
- ☞ ***Locusta** (Desert locust) is the gregarious, migratory pest of crops.*
- ☞ *Economically useful insects e.g. **Apis** (Honeybee), **Bombyx** (silk worm), **Laccifer** (lac insect), etc.*

- *OTHER ARTHROPODS*
  - ☞ *Main eyes of spiders are ocelli that can form images.*
  - ☞ *There is no external segmentation in mites.*
  - ☞ *Many crustaceans and a few centipedes have blue-coloured copper containing haemocyanin pigment in their blood plasma.*
  - ☞ ***Limulus (King crab).** A **living-fossil** representative (about 190 million years old species).*
  - ☞ ***Palamnaeus or Buthus (Scorpion) :** Body is divided into two parts : cephalothorax and abdomen. Abdomen has a **poison claw** at posterior end. Sexes show a copulatory dance. Female is **viviparous.***
  - ☞ ***Ticks** and **mites** are sanguivorous and parasitic arachnids. e.g. Boophilus (common cattle tick) and Sarcoptes (Itch mite).*
  - ☞ *Scorpion was picturized by **Walt Disney** in **"Living Desert".***
  - ☞ *Spiders have **spinnerets** on ventral side of abdomen which help in weaving web by the secretion of silk glands.*

Main reasons for the success of arthropods is the presence of a **sclerotized skeleton** formed of heteropolysaccharide **(chitin)** and proteins. It helps in :

1. Protection from the predators because it is tough due to deposition of minerals like calcium phosphate and carbonate.

2. It helps in providing a **definite shape.**

3. It prevents excessive loss of water because it is **water proof.**

4. It is modified to form **wings** which help in **flying.**

5. It provides surface for **muscle-attachment.**

6. It forms the mandibles which help in **biting** and **chewing.**

7. It lines **tracheae** which help in **respiration.**

8. It forms **claws** or **pincers** for grasping.

FIVE TYPES OF METAMORPHOSIS IN INSECTS

1. Ametaboly. Development includes **no metamorphosis**. The young resembles the adult in form, structure and mode of life. It simply grows in size to become adult. It is found in **silver fish.**

2. Paurometaboly or Gradual metamorphosis. The young, called **nymph**, resembles the adult insect in form and mode of life but is without wings and gonads. During gradual metamorphosis, wings and gonads are developed. It is found in **cockroach, grasshopper, termites, bugs**, etc.

3. Hemimetaboly or Incomplete metamorphosis : The young, called **naiad**, is aquatic so differs from the adult in structure as well as mode of life. Young has gills for respiration and is wingless. During metamorphosis, gills are replaced by tracheae and wings are developed. It is found in **dragon flies** and **damsel flies.**

4. Holometaboly or complete metamorphosis. The hatched young, called **larva**, differs from the adult in form, structure and mode of life. Larva is generally worm-like. The larva of butterflies and moths is called **caterpillar** (with true as well as pseudolegs); called **maggot** (legless) in houseflies; called **grub** (with only true legs) in beetles; and called **wriggler** in mosquitoes. It grows gradually to become fully grown. The larva changes into an inactive, non-feeding and non-locomotory stage called **pupa** which undergoes both **histolysis** (breakdown of unwanted organs) and **histogenesis** (development of new organs) to become adult (**Imago**). The period between two moultings is called **stadium** while young stage during the stadium is called an **instar.** It is found in **butterflies, moths, houseflies, mosquitoes, bees, wasps, ants** etc.

5. Hypermetaboly or Hypermetamorphosis. In this, each larval stage or nymph differs from the other in habits, food and mode of living. It is found in **Blister beetle.**

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Table 14. Types of mouth parts in Insects.

Type of mouth parts	Examples
1. **Biting and chewing type**	Locusts, Grasshoppers, Crickets, Cockroaches, Mantids, Silver fish
2. **Piercing and sucking type**	Mosquitoes, Bed bugs, Rat fleas, Aphids, etc.
3. **Chewing and lapping type**	Honey bees
4. **Sponging type**	House fly
5. **Siphoning type**	Butter flies and Moths.

PRACTICE PROBLEMS – ANNELIDA AND ARTHROPODA

44. Name the locomotory organs in three classes of phylum Annelida.
45. What is clitellum? Give its function.
46. What are annuli? What is their function.
47. How does class Polychaeta differ from other classes of phylum Annelida?
48. Though the earthworm is bisexual, but even then always cross-fertilization occurs. Give the reason.
49. What are genital papillae? Give their position and function.
50. Why is earthworm called a Nature's ploughman?
51. What is *Heteronereis*?
52. Name the anticoagulant found in the saliva of leeches.
53. What do you mean by sanguivorous mode of feeding?
54. Give the most important cause of success of insects.
55. List three peculiar characters of phylum Arthropoda.
56. Name the excretory organs of crustaceans (e.g. prawn) and insects (e.g. cockroach).
57. Why is *Peripatus* called a connecting link between annelids and arthropods?
58. List two differences between chilopods (e.g. centipede) and diplopods (e.g. millipede).
59. Give two peculiar characters of class Insecta.
60. Discuss sexual dimorphism in cockroach.
61. Differentiate a butterfly and a moth.
62. What are pleopods? Give their function.
63. What is caste composition in a hive of honey bee?
64. Name a viviparous arthropod. To which class, it belongs to?
65. List two differences between a spider and an insect.

ANSWERS TO PRACTICE PROBLEMS

44. (i) Oligochaeta = **setae;** (ii) Polychaeta = **Parapodia;** (iii) Hirudinea = **Suckers.**
45. A **glandular band** in earthworm which secretes **ootheca** or egg case.
46. **Ring-like grooves** in the annelids which divide the body into segments, **metameres.**
47. Polychaetes are unisexual, have **parapodia** with many setae for locomotion but no-clitellum. Gonads are temporary. Development includes **trochophore larva.**
48. Earthworms is **protandrous** in which testes mature earlier than ovaries.
49. Two pairs of ridges in earthworm (one pair in each of 17th and 19th segments). These **help in copulation** as these keep the copulants together.
50. It **increases soil fertility** as brings mineral–rich subsoil on the surface.
51. **Reproductive phase** of *Nereis.* Its posterior part of body has large sized parapodia with oar-like setae.
52. **Hirudin.**
53. **Sucking blood** of other animals.
54. Presence of **sclerotised exoskeleton.**
55. (i) **Jointed legs** (ii) **Mouth parts** (iii) **Haemocoel.**
56. (i) Crustaceans : **Antennary glands;** (ii) Insects = **Malpighian tubules.**
57. *Peripatus* has **nephridia** and unjointed legs (like annelids); and **haemocoel** and tracheae (like insects).
58. **Centipede** has two body parts (head and trunk) and one pair of legs on each segment of trunk.
Millipede has three body parts (Head, thorax and abdomen). Each thoracic segment has one pair of legs while each abdominal segment has two pairs of legs.
59. (i) Three body parts (Head, thorax and abdomen) and (ii) Three pairs of legs on thorax.
60. Male cockroach has **anal styles** but no brood pouch.
Female cockroach has **brood pouch** but no anal styles.
61. A **butterfly** is diurnal, has knobbed antennae and wings are upward directed at rest.
A **moth** is nocturnal, has feathery antennae and wings are outward directed at rest.
62. These are oar-like **abdominal appendages** of prawn and help in swimming.

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63. (i) **Drones** (Haploid males, developed parthenogenetically); (ii) one **Queen** (2N–fertile female) and (iii) workers (2N–sterile females).
64. **Scorpion.** It belongs to class **Arachnida.**
65. **Spider** has two body parts (cephalothorax & abdomen). It has four pairs of legs.
Insect has three body parts (Head, thorax & abdomen). Thorax has three pairs of legs, so called **Hexapoda.**

PHYLUM-MOLLUSCA

(Soft Bodied Animals) (*L. mollis* — soft)

Characters (Fig. 16) :

1. All molluscs are **soft-bodied animals.**

2. These have **organ-system organisation** and are generally **bilaterally symmetrical** except snails which are asymmetrical as their shell is spirally-coiled.

3. Germ layers. These are **triploblastic** animals.

4. Molluscs are **true-coelomates** but **haemocoelomates.** These are **non-metameric** animals.

5. Body division. Body is unsegmented and divided into **three parts:** Ventral soft and muscular **foot** (locomotion), **head** (with sensory tentacles) and dorsal **visceral mass.** Head is absent in bivalves.

6. Skin of visceral mass secretes a glandular fold, called **mantle or pallium.** The space between mantle and visceral mass is called **mantle** or **pallial cavity.**

7. Mantle secretes a **calcareous (of $CaCO_3$) shell.** Shell is generally external but may be internal (e.g. *Sepia*) or absent (e.g. *Octopus*).

8. Digestive tract is complete. Buccal mass of gut is generally with a **rasping and feeding organ, radula.** Digestive gland is **hepatopancreas.**

9. These respire with the help of **gills** (in aquatic forms) or **pulmonary sac** (in terrestrial forms).

10. Circulatory system. It is of **open type.** Colour of blood is **blue** due to presence of a **copper-containing haemocyanin** generally dissolved in plasma. But the cuttlefishes have closed blood vascular system.

11. Excretion. It occurs by 1 or 2 pairs of **kidneys** (called **metanephridia**). Ammonia is chief excretory matter. Some have **organs of Bojanus.**

12. Molluscs have a peculiar sense organ, **osphradium,** to test the chemical nature of ingoing water current. Some have **statocysts** for balancing.

13. Nervous system. It is formed of a few pairs of ganglia joined by nerve connectives and commissures.

14. Sexes are generally **unisexual.** Fertilization may be external or internal. Development may be **direct** or **indirect.** Main larval forms found are **glochidium** or **trochophore** or **velliger.**

15. Habitat. These are mostly marine though some occur in fresh-water (e.g. *Unio*) and some occur in damp soil (e.g. *Limax*)

Phylum Mollusca is the **second largest phylum** after Arthropoda and includes **over 100,000** species.

Examples (Fig. 16) : *Neopilina*, *Pila* (Apple snail), *Pinctada* (Pearl oyster), *Sepia* (Cuttle fish), *Loligo* (Squid), *Octopus* (Devil fish), *Aplysia* (Sea hare), *Dentalium* (Tooth shell), *Chaetopleura* (Chiton), *Unio*, etc.

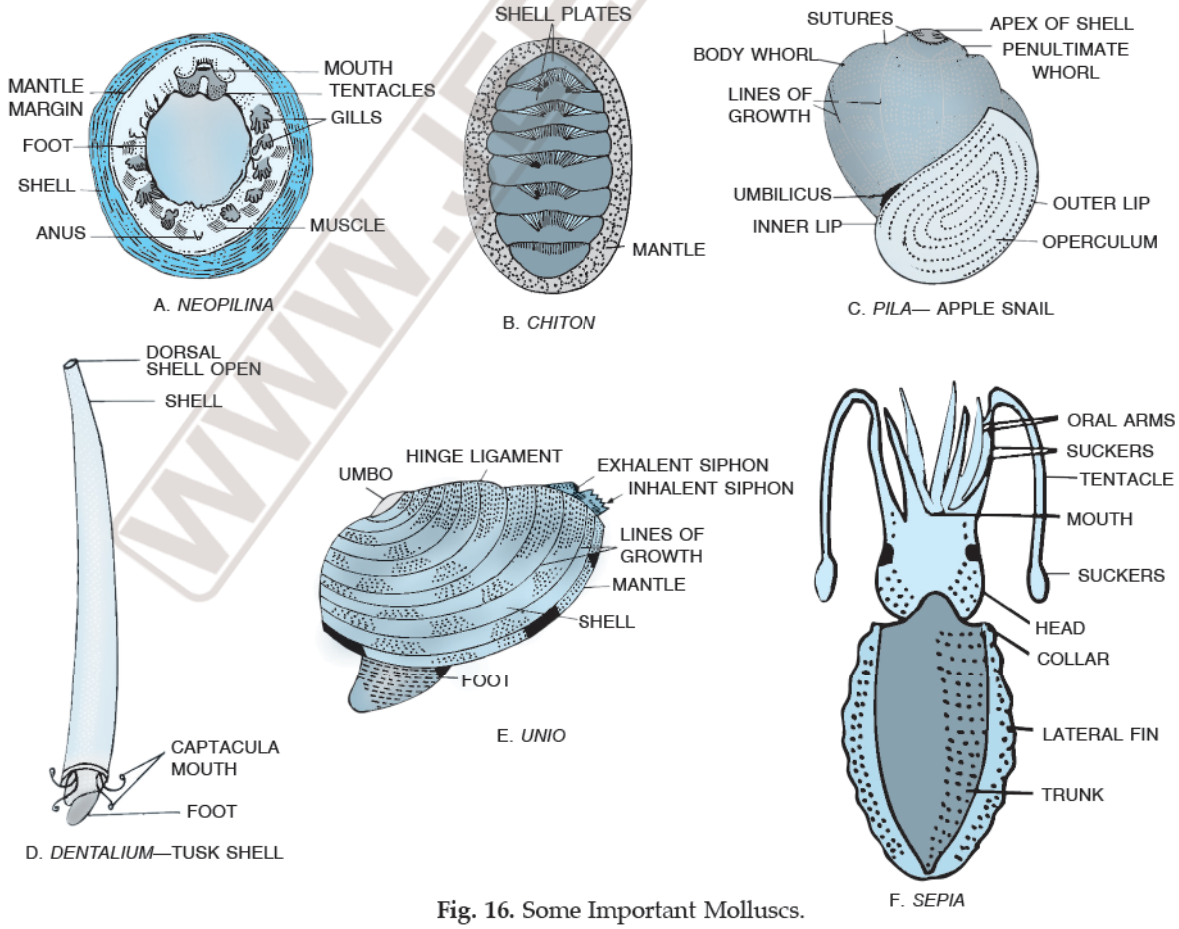

Fig. 16. Some Important Molluscs.

CLASSIFICATION OF MOLLUSCA FOR COMPETITIVE EXAMINATIONS

Phylum Mollusca is divided into **six classes** on the basis of **foot and shell :**

A. Class Monoplacophora. (i) Foot is **sole-like. (ii)** Shell is formed of **only one plate** and is cup or spoon shaped *e.g., Neopilina.*

B. Class Amphineura (i) Foot is sole-like or reduced or absent. **(ii)** Shell is formed of 8 **plates** or absent *e.g. Chiton.*

C. Class Gastropoda. It is the **largest class** of Mollusca. **(i)** A part of foot is modified into stomach. **(ii)** Shell is spirally coiled, univalvular and unilocular *e.g., Pila* **(Pond snail** or **Apple snail)**; *Limax* **(slug)**; *Cypraea* **(cowrie)**; *Aplysia* **(sea hare)**.

D. Class Bivalvia or **Pelecypoda**. **(i)** Foot is **wedge-shaped (ii)** Shell is formed of 2 **valves** hinged dorsally *e.g., Unio* **(Fresh-water mussel)**; *Pinctada* **(Pearl oyster):** *Teredo* **(Shipworm)**; *Solen* **(Razor shell)**; *Mytilus* **(marine mussel)**; etc.

Some bivalves secrete **pearls.** A pearl is formed of a number of nacreous layers secreted by nacre-secreting cells of mantle around a foreign body. **Most valuable pearl is formed by** *Pinctada margaritifera.*

E. Class Scaphopoda. (i) Foot is **conical** for digging **(ii)** Shell is like **elephant - tusk** open at both ends. *e.g. Dentalium.*

F. Class Cephalopoda or **Siphonopoda**. **(i)** Shell may be internal (*Sepia*) or external (*Nautilus*) or absent (*Octopus*). **(ii)** Foot is partly modified into head with **8 or 10 arms** and partly into **siphon (iii)** Head and foot are fused. *e.g., Sepia* **(Cuttle fish)**; *Loligo* **(Squid or sea arrow)**; *Octopus* **(Devil fish)** and *Nautilus* **(Pearly nautilus).**

ADDITIONAL USEFUL INFORMATIONS ABOUT MOLLUSCA FOR COMPETITIVE EXAMINATIONS

- ***Malacology :*** *Study of molluscs.* ***Conchology :*** *Study of shells. Term Mollusca was coined by* ***Lamarck.***
- ***Torsion :*** *Twisting of visceral mass in the snails of Gastropoda through an angle of 180° due to which snails become asymmetrical.*
- ***Pallial complex :*** *All the organs present in the mantle or pallial cavity.*
- ***Gastropoda*** *is* ***largest class*** *of Mollusca (with about 35,000 living species). It is characterised by* ***torsion.***
- *In molluscs, true coelom is greatly reduced and is restricted to pericardial cavity (around the heart) and around the kidneys and gonads.*

A. MONOPLACOPHORA

- ***Neopilina*** *acts as a* ***connecting link*** *between* ***Annelida*** *(Metameric segmentation, nephridia and trochophore larva) and* ***Mollusca*** *(Mantle, shell and radula). It is also an example of* ***Living fossil.*** *It is a segmented mollusk.*

B. AMPHINEURA

- ***Chiton :*** *Shell is formed of 8 plates so called* ***polyplacophoran.***

C. GASTROPODA

- ***Pila globosa (Apple or Pond snail) -***
  - *An* ***amphibious*** *mollusk so respires with gill in water and palmonary sac on land.*
  - *Snail shell is either* ***dextral*** *(mouth of shell rightward) or* ***sinistral*** *(mouth of shell towards left side).*
  - ***Gill,*** *also called* ***ctenidium,*** *of Pila is* ***monopectinate*** *(with one row of gill lamellae from gill axis) and* ***pectinibranch.***
  - ***Osphradium*** *is a* ***bipectinate*** *(with 2 rows of leaflets) and chemosensory (tests incoming water) structure.*
- ***Patella*** *is a marine gastropod, commonly called* ***true limpet.*** *It has an* ***aspidobranch gill*** *(feather-like with 2 rows of gill lamellae).*
- ***Aplysia :*** *Commonly called* ***Sea hare.*** *It has 2 pairs of tentacles. Posterior pair is large sized and called* ***rhinophores.***
- ***Limax.*** *A* ***terrestrial*** *gastropod and is commonly called* ***grey slug.*** *It creeps on a self-secreted mucus tract.*

D. SCAPHOPODA

- ***Dentalium :*** *It is marine and fossorial. Shell is tusk-like so called* ***tusk*** *or* ***tooth shell.***

E. PELECYPODA :

- *Bivalves secrete* ***pearls.*** *A pearl is formed of a number of nacreous layers secreted by nacre-secreting cells of mantle around a foreign body. The pearl of Unio is not of commercial important. Most valuable pearl of* ***Pinctada margritifera,*** *commonly called* ***pearl oyster. Kokichi Mikimota*** *is commonly called* ***"Father of pearl industry."***
- ***Marsupium :*** *Enlarged water tube of Unio and acts as* ***brood pouch.***
- ***Pecten :*** *Commonly called* ***scallop.*** *It is a marine and* ***free-swimming*** *and swims by clapping movements of shell valves.*
- ***Mytilus (Sea mussel) :*** *A marine bivalve and is fixed to rocks, etc. by a group of adhesive* ***byssal threads.***
- ***Solen*** *is commonly called* ***razor clam,*** *while* ***Teredo*** *is commonly called* ***ship worm.*** *Teredo bores through wood of ship.*

F. CEPHALOPODA

- *Cephalopods have* ***ink glands*** *which are concerned with protection.*
- ***Sepia (Cuttle fish) :*** *It is* ***marine,*** *good swimmer and carnivorous. Third right arm of male is* ***hectocotylised*** *to transfer sperms in female. Head has four pairs of arms and two tentacles. Trunk bears two lateral fins.*

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- ***Loligo** (**Squid** or **sea arrow**) : Similar to Sepia except that the fins are present only in the posterior half and meet posteriorly. **Giant squid (Architeuthes longpinus) is largest sized invertebrate (about 55 ft.).***
- ***Octopus (Devil fish) :** An octopod marine mollusc with 8 sucker being arms but no tentacles. It kills the prey with its **poisonous saliva.** It has good learning power and can be trained. Internal shell is absent.*
- ***Sepia, Loligo** and **Octopus** have **ink glands** which secrete a coloured cloud for defence from the predator.*

PHYLUM ECHINODERMATA

(Gr. *echinos* = spines or Hedgehog; *derma* = skin)
(Spiny-skinned Animals)

Characters :

1. Body is covered by large number of **spines.**

2. These have **organ-system organisation** and are **triploblastic.**

3. Adults have **pentamerous-radial symmetry** while larvae are bilaterally symmetrical. The radial symmetry of echinoderms is regarded as a **secondary acquisition**.

4. These are **true-coelomates.** True coelom is **enterocoelic** (formed from enteron of gastrula). Coelomic fluid has **coelomocytes**.

5. These have **water-vascular system** or **ambulacral system** in which water enters through a porous plate called **madreporite.** It helps in **locomotion**, by exerting hydraulic pressure.

6. Organs of locomotion are **tube feet** or **podia.** These also help in anchorage, capturing and handling of food and respiration. Tube feet are usually present in five radially-arranged **ambulacra** alternating with five **interambulacra** with no tube feet.

7. Habitat. These are exclusively **marine** and **benthonic.** It has no fresh water or terrestrial representative.

8. These have good power of **autotomy** and **regeneration.**

9. Body wall is formed of single layered **ciliated epidermis** lying over mesodermal dermis of connective tissue having **calcareous ossicles (endoskeleton)** produced into spines.

10. Respiration occurs by **dermal branchiae** (gills) or **papulae** and tube feet.

11. Excretory system is absent. Excretion occurs through body surface and are **ammonotelic.**

12. Circulatory system is of **open type** and is called **haemal system.** Heart is absent. Blood has no pigment.

13. These are usually **unisexual** or **dioecious** with no sexual dimorphism. Fertilization is always external. Development always includes a **free-swimming, ciliated and bilaterally symmetrical larva** in life cycle.

14. Phenomena of **autotomy** and **regeneration** are well marked in the echinoderms.

It includes about **7,000 living species.**

Affinities of Echinoderms with Chordates

Embryonic development of echinoderms shows a number of similarities with those of chordates which suggests that the chordates have evolved from Echinoderm-like ancestors.

1. Cleavage in both is **radial** and **indeterminate.**
2. Gastrulation occurs by **invagination.**
3. Deuterostomous (blastopore forms anus).
4. Coelom is **enterocoelic.**
5. Mesodermal endoskeleton.

CLASSIFICATION OF ECHINODERMATA FOR COMPETITIVE EXAMINATIONS

Classification. Echinodermata is divided into **5 classes on the basis of body shape, position of madreporite and kind of larval form :**

A. Class Asteroidea (Gr. *aster* = star; *eidos* = form). **(i) Star-shaped** body in which 5 arms are not demarcated from central disc. **(ii)** Madreporite is on aboral side. **(iii)** Development includes **Bipinnaria** or **Brachiolaria** larva *e.g., Asterias* **(Starfish)**, *Pentaceros* **(Starfish).**

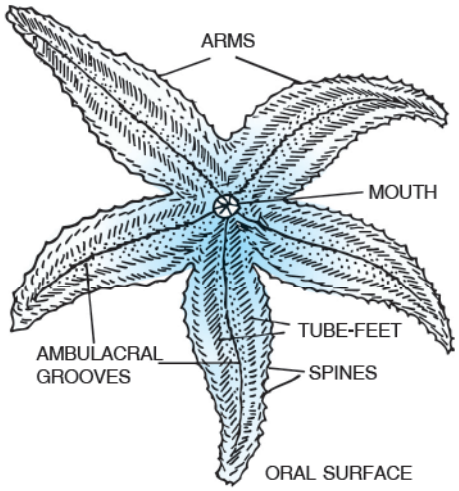
B. Class Ophiuroidea. (i) Star shaped body in which 5 arms are demarcated from central disc. **(ii)** Madreporite is on oral side. **(iii)** Development includes **Ophiopluteus larva** *e.g., Ophiothrix* **(Brittle star)**, *Asterophyton* **(Basket star).**

C. Class Echinoidea. (i) Body is **globular with no arms.** Also has **movable spines. (ii)** Madreporite is on aboral side. **(iii)** Development includes **echinopluteus** larva. **(iv)** Presence of a masticatory structure, **Aristotle's lantern** *e.g. Echinus* **(Sea-urchin)**, *Clypeaster* **(Cake-urchin)**, *Echinocardium* **(Heart urchin)**.

D. Class Holothuroidea. (i) Body is elongated and **cucumber-like** with no arms. **(ii)** Madreporite is towards oral side and is internal. **(iii)** Development includes **auricularia** larva *e.g., Holothurion* **(Sea - cucumber)**, *Cucumaria* **(Sea - cucumber).**

E. Class Crinoidea. (i) Body is lily flowerlike in which each arm is divided in two sub-arms and each sub-arm has **pinnules. (ii)** Madreporite is absent. **(iii)** Development includes **doliolaria** larva *e.g., Antedon* **(Sea-lily** or **feather star)**.

Examples (Fig. 17) : *Asterias* (starfish), *Echinus* (sea urchin), *Ophiura* (Brittle star), *Cucumaria* (sea cucumber), *Antedon* (feather star or sea lily), etc.



A. *ASTERIAS*—STAR FISH.

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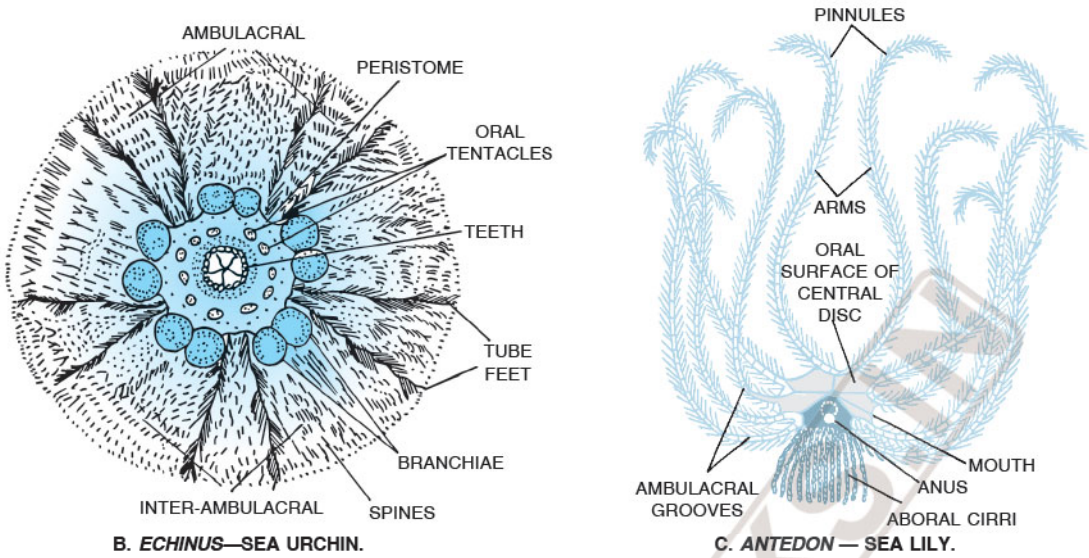

B. *ECHINUS*—SEA URCHIN. C. *ANTEDON* — SEA LILY.

Fig. 17. A. *Asterias* (star fish); **B.** *Echinus* (Sea urchin); **C.** *Antedon* (Sea lily)

ADDITIONAL USEFUL INFORMATIONS ABOUT ECHINODERMATA FOR COMPETITIVE EXAMINATIONS

- *Echinodermata constitutes the only major group of deuterostome invertebrates. It is second largest grouping of deuterostomes after the chordates.*
- *Echinoderms lack head as well as brain.*
- *Pedicellariae are pincer-like structures found in many echinoderms like sea stars and see urchins. These keep the body surface clear of algae, debris and microorganisms.*
- *Water vascular system is of **coelomic** in origin. Endoskeleton is formed of calcareous **dermal ossicles.***
- *Basic larval form of echinoderms is **dipleurula** which undergoes a very complex metamorphosis.*
- ***Asterias (Starfish) -***
  - *Commonly known starfishes are : Asterias, Pentaceros, Astropecten, Solaster, Heliaster, Asterina, etc.*
  - *Marine and benthonic echinodermate. Body is formed of a central disc and five arms. Madreporite is aboral while mouth is oral in position.*
  - *Digestion is **extra corporeal** (digestive juices released outside to digest prey).*
  - *Development includes **dipleurula, bipinnaria** and **brachiolaria** larva.*
- ***Pedicellariae :** Pincer-like structures on the body surface of starfish and prevent the settling of debris and other organisms.*
- ***Echinus (Sea urchin) :** Echinodermate with no arms. Mouth has toothed **Aristotle's lantern** to masticate food. Tubefeet and movable spines help in creeping.*
- ***Cucumaria (Sea cucumber) :** A fossorial echinodermate. Development includes **auricularia** larva.*

PHYLUM HEMICHORDATA OR STOMOCHORDATA

(Gr. *hemi* = half; *chordata* = notochord)

Characters :

1. Body divisions. **Worm-like** body is divisible into 3 **parts : proboscis, collar** and a long **trunk**.

2. Gill slits. Many pairs of gill slits in the pharyngeal region for branchial respiration.

3. Tail. These have **no tail.**

4. Stomochord. It is a hollow mesodermal outgrowth which arises from the roof of **buccal cavity** and is considered a "**buccal diverticulum**".

5. These are **triploblastic** and **enterocoelomate** animals with **organ-system organisation** and **bilateral symmetry.**

6. Gut is **complete** and is straight or U-shaped. These feed on small-sized organic particles and are generally **filter feeders**.

7. Proboscis gland or **glomerulus** is organ of excretion.

8. Circulatory system is of **open** type.

9. Sexes are usually unisexual. Fertilisation is external. Development usually includes a **tornaria larva.**

10. Habitat. Exclusively **marine** and **tubicolous**.

There are only about **100 species** of Hemichordates.

Example : *Balanoglossus*–**(Fig. 18) (Tongue or Acorn worm),** *Saccoglossus* and *Rhabdopleura*

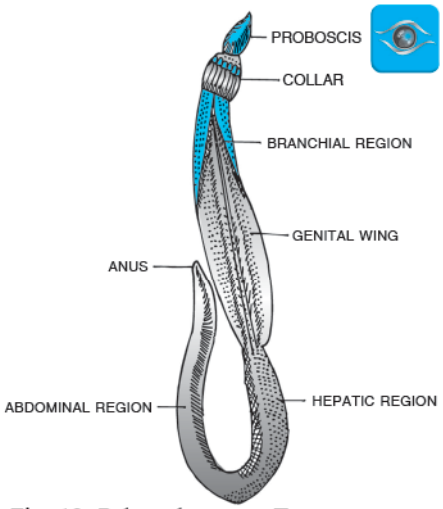

Fig. 18. *Balanoglossus* — Tongue worm.

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NOTE

- *Chiton* is an edible mollusc and is commonly called **sea beef.**
- **Sea cucumber** (*Holothurion*) can lose its viscera in self-defence (called **evisceration**).
- In hemichordates, the coelom is divisible into 3 compartments : Protocoel, mesocoel and metacoel.
- ***Balanoglossus* (Tongue or Acorn worm)** acts as a **connecting link** with echinoderms and chordates.
- **Parker and Haswell** (1962) : Created Subphylum Hemichordata under phylum Chordata.
- **Barnes** (1974) : Raised it to phylum Hemichordata under invertebrates.
- In Hemichordates, enterocoelic coelom is divisible into protocoel, mesocoel and metacoel.

PRACTICE PROBLEMS – MOLLUSCA AND ECHINODERMATA

66. List two peculiar characters of phylum Mollusca.
67. What is osphradium? Give its function.
68. Why is *Neopilina* called a connecting link between Annelida and Mollusca.
69. What is pearl? Name the mollusc which provides most valuable pearl.
70. Which is the most advanced class of Mollusca. Give two examples of this class.
71. Discuss the mode of respiration in *Pila.*
72. What is torsion? What is its effect?
73. What is radula? Give its function.
74. Why are echinodermates called spiny-skinned animals?
75. What are tube feet? Give their function.
76. Which peculiar type of system is found only in the echinodermates?
77. List two similarities between echinodermates and chordates.
78. Name the larval stage found in the life history of star fish and sea urchin.
79. Why is *Antedon* called living fossil?
80. What is Aristotle lantern? Give its function.
81. Give two peculiar characters of phylum Hemichordata.
82. Why is *Balanoglossus* called a connecting link between echinodermates and chordates.

ANSWERS TO PRACTICE PROBLEMS

66. (i) **Soft-bodied** (ii) Presence of **pallium** or mantle (iii) Mostly external **shell.**
67. A peculiar **chemoreceptor** sense organ which tests ingoing water current in mollusc.
68. *Neopilina* has both **annelid characters** (e.g. nephridia and metameric segmentation) and **molluscan - characters** (e.g. shell, mantle and radula).
69. A pearl is formed of many nacreous layers around a foreign body. *Pinctada margritifera.*
70. **Cephalopoda** e.g. *Sepia* (cuttle-fish) and *Loligo* (sea-squid).
71. *Pila* respires with **gill** in water while respires with **pulmonary sac** on land.
72. Twisting of visceral mass in the snails through an angle of 180°. It makes the snail asymmetrical.
73. A **rasping organ** in the buccal mass of certain mollusks. It has many rows of teeth and acts as a **masticatory organ.**
74. As their body is covered with **many spines.**
75. These are tubular parts of water vascular system of echinoderms. These are **locomotory** organs of them.
76. Water-vascular system.
77. (i) Deuterostomous condition (ii) Coelom is formed from archenteron of gastrula.
78. (i) Starfish = **Bipinnaria.** (ii) Sea urchin = **Echinopluteus.**
79. *Antedon* (Feather-star) has many primitive characters but is still living.
80. It is calcareous and toothed structure found in the sea urchins. It helps in capturing food.
81. (i) Many pairs of **gill slits.** (ii) **Stomochord** as a hollow outgrowth of roof of buccal cavity.
82. *Balanoglossus* has both echinodermate characters and chordate characters.

PHYLUM CHORDATA

(*L. chorda* = rod; *ata* = group)

Characters :

It is the most advanced animal phylum and includes about **45,000 living species.** All the chordates **have certain diagnostic features (Fig. 19) :**

1. Notochord. These have a solid and unjointed mesodermal rod of vacuolated cells called **notochord** on dorsal side between alimentary canal and nervous system. It acts as **primary axial skeleton** and is surrounded by a **notochordal sheath.**

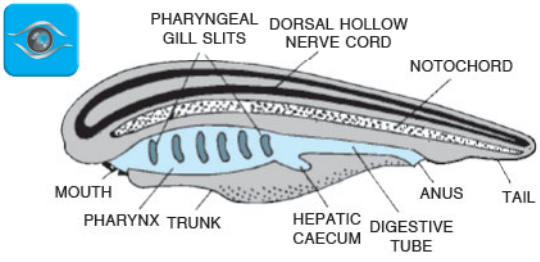

Fig. 19. General chordate plan.

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Table 15. Differences between Chordates and Non-chordates.

Characters	Chordates	Non-chordates
1. Notochord	Present at least in some stages of development.	Never present.
2. Central nervous system	Dorsal, hollow, single and non-ganglionated.	Ventral, solid, double and ganglionated.
3. Gill slits	Present on lateral side of pharynx in some stages or throughout life.	Never present.
4. Tail	Present in some stages or throughout life.	Generally absent.
5. Position of heart	Ventral.	Dorsal.
6. Haemoglobin	Present in the RBCs.	When present it is dissolved in blood plasma.
7. Flow of blood	Forward in ventral vessel and backward in dorsal vessel.	Backward in ventral vessel and forward in dorsal vessel.

2. Central Nervous System (CNS). It is always **dorsal** and **hollow.** It is generally differentiated into anterior broader **brain** and posterior narrow, non-ganglionated and longer **spinal cord.** It lies dorsal to the notochord.

3. Gill slits. These are paired apertures present on the lateral sides of pharynx and help in **respiration.**

4. Tail. It is **post-anal** or **post-cloacal** part of body.

These four primary chordate characters are always present during embryonic development but may be present throughout life or one or more of these may be reduced or lost during the development.

Other chordate characters are: bilateral symmetry; triploblastic nature; organ-system organisation; metamerism; cephalization; endoskeleton; enterocoelic coelom; closed circulation and special respiratory and excretory organs.

Classification :

Phylum chordata is divided into 3 **sub-phyla** on the basis of **fate** of **notochord:**

A. UROCHORDATA B. CEPHALOCHORDATA
C. VERTEBRATA

A. SUB-PHYLUM UROCHORDATA (TUNICATA)

(Gr. *uros* = tail; *chorda* = rod; *ata* = group).

1. Notochord is present only in **tail of larva** and is lost during metamorphosis, so adult is tailless. So these are called **urochordates.**

2. CNS is also lost during metamorphosis. Adult has solid dorsal ganglion.

3. Body is covered by a leathery **test** or **tunic** formed of **tunicin** (carbohydrate) (also called **animal cellulose**), so called **tunicata.**

4. Usually ciliary mode of feeding.

5. Open type circulatory system with ventral heart and periodic reversal of blood flow.

6. There are numerous gill slits or **stigmata** on the lateral walls of pharynx so called **branchial - basket.**

7. Stigmata open into an ectodermal-lined cavity called **atrium.**

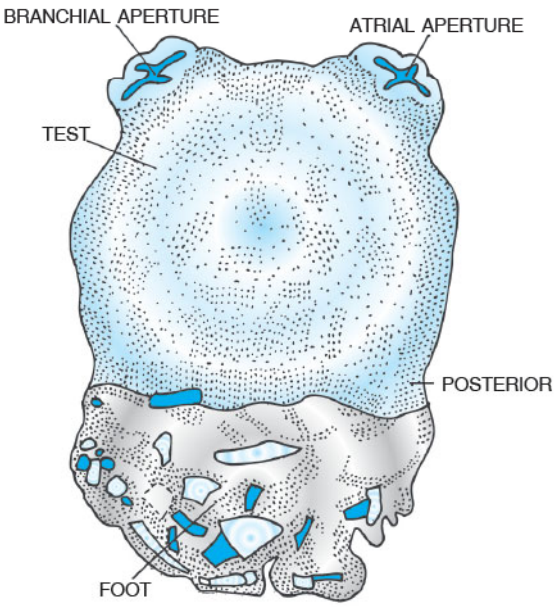
8. Excretion occurs by **neural gland.**

9. These show **retrogressive metamorphosis.**

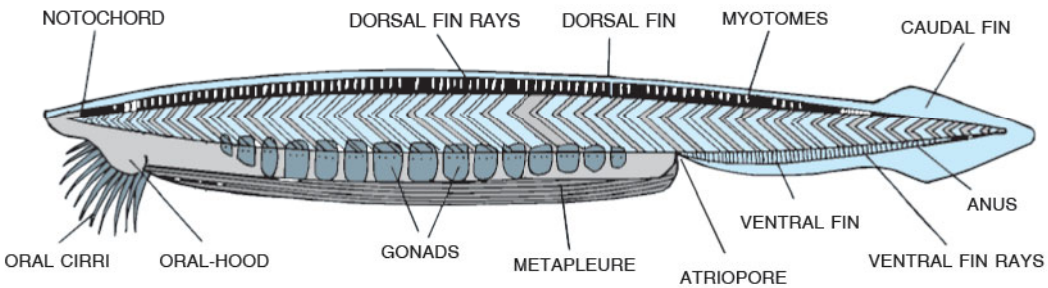
10. These are **marine,** mostly sedentary and **filter-feed.**

There are about **1,300 species** of Urochordates.

Examples: *Herdmania* **(Sea squirt) (Fig. 20A);** *Salpa; Doliolum; Ascidia; Oikopleura* etc.



A. *HERDMANIA* - SEA SQUIRT



B. *AMPHIOXUS* (LANCELET)

Fig. 20. A. *Herdmania* - Sea squirt; **B.** *Amphioxus* - Lancelet.

Table 16. Differences between Urochordates and Cephalochordates.

Character	Urochordates	Cephalochordates
1. Position of notochord	Present only in the tail of larva. Tail and notochord are lost during metamorphosis.	Present throughout the body and persists throughout life.
2. Nerve cord	Present only in larva and is also lost during metamorphosis.	Well developed hollow nerve cord is present dorsal to notochord.
3. Metamorphosis	Retrogressive metamorphosis.	Progressive metamorphosis.
4. Examples	*Herdmania.*	*Amphioxus.*

B. SUB-PHYLUM CEPHALOCHORDATA

(Gr. *cephalo* = head; *chorda* = rod; *ata* = group).

Characters :

1. Notochord extends from head to tail of body, so called **cephalochordates.** Notochord persists throughout life.

2. CNS is present but is not differentiated into brain and spinal cord.

3. Pharynx has numerous gill slits so called **branchial basket.**

4. Tail is present throughout life.

5. Cephalochordates are fish-like, small-sized **marine** chordates.

6. Dorsal, caudal and anal fins are continuous. Paired fins are absent.

7. Body muscles are arranged as a series of V-shaped blocks of striated muscles, called **myotomes**.

8. Epidermis is single layered.

9. Blood vascular system is **closed type** but heart is absent.

10. Excretory organs are **protonephridia** with solenocytes.

There are about **23 species** of cephalochordates.

Example: *Amphioxus (Branchiostoma)* **(Lancelet).**

Both urochordates and cephalochordates are collectively called **Protochordates** (primitive chordates) or **Acraniates** (no cranium or brain-box) or **non-vertebrate chordates.** These are exclusively **marine**.

C. SUB-PHYLUM VERTEBRATA OR CRANIATA

Characters :

1. Notochord or **chorda dorsalis** is present during the embryonic period but is replaced by a rod of cartilaginous or bony rings, **vertebrae,** and is called **vertebral column** or backbone, so called **vertebrata.** This shows that **all the vertebrates are chordates but all the chordates are not vertebrates.**

2. CNS is differentiated into **brain** and **spinal cord.** Brain is protected by a **brain-box** called **cranium,** so called **craniata.**

3. Epidermis is many layered, called **stratified epithelium.**

4. These show **internal metamerism** of ribs, vertebrae, muscles, nerves etc.

5. Excretory organs are one pair of **kidneys** for **excretion** and **osmoregulation.**

6. Circulatory system is **closed** type. Blood is red and **haemoglobin** is present in RBCs. Heart is ventrally located and is 2 or 3 or 4 chambered.

7. Respiration occurs by **gills** or **skin** or **lungs.**

8. These have **organ-system organisation, bilateral symmetry** and are **triploblastic.**

9. These have an **endoskeleton** of cartilages or bones or both.

10. Different animal groups of vertebrates have different types of **exoskeleton** *e.g.*, **hairy** exoskeleton (mammals), **feathery** (birds) or **scaly** (fishes and reptiles).

11. These generally have **two pairs** of **lateral appendages** like **fins** in fishes and **limbs** in tetrapods.

12. These are unisexual and have **one pair of gonads.**

13. These have **endocrine glands** which secrete hormones to regulate the body functions.

Classification : Subphylum Vertebrata is divided into 2 **sub-divisions** on the **basis** of **jaws:**

1. AGNATHOSTOMATA (*a* = without; *gnathos* = jaw; *stoma* = mouth; *ata* = group), and

2. GNATHOSTOMATA.

1. AGNATHOSTOMATA : (a) Mouth is not bounded by jaws, so called **agnathans (jawless vertebrates).**

(b) Notochord persists throughout life.

(c) Exoskeleton and paired appendages are absent.

(d) Internal ear has one or two **semi-circular canals.**

Single class - **CYCLOSTOMATA** (Gr. *cyklos* = circular; *stoma* = mouth)

Characters :

(a) Presence of **circular mouth** bounded by **suctorial funnel** but is jawless. Funnel has **horny sheath** having horny teeth.

(b) Their body is long, **eel-like**. These are generally ectoparasites on the fishes.

(c) Median fins present but paired fins and associated girdles are absent. Fins are supported by cartilaginous fin rays.

(d) Single nostril (monorhinus) present. Nasal chamber is closed and does not open in buccal cavity.

(e) Skin is **without scales** and slimy.

(f) Endoskeleton is **cartilaginous** but exoskeleton (scales) is absent.

(g) Heart is 2 **chambered.**

(h) Lateral-line sense organs are present. A **functional pineal eye** is present.

(i) Respiration occurs by 6 to 15 pairs of **internal gills** in their gill pouches. Branchial arches are internally positioned.

(j) Sexes are **unisexual**. Gonad is single and without a gonoduct. These migrate to fresh water for spawning. Development of lampreys generally includes

an **ammocoetes larva** resembling *Amphioxus* in structure and functioning.

(k) These are **poikilothermal** or cold blooded.

(l) These are **either marine or fresh-water** vertebrates. It has about **42 species**.

Examples : *Petromyzon* **(Sea-lamprey) (Fig. 21)** and *Myxine* **(Hag fish).**

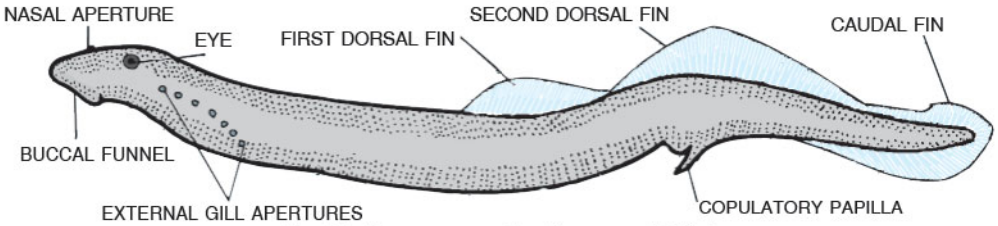


Fig. 21. *Petromyzon*—Sea lamprey (Male).

ADDITIONAL USEFUL INFORMATIONS ABOUT HEMICHORDATA, UROCHORDATA, CEPHALOCHORDATA AND AGNATHANS FOR COMPETITIVE EXAMINATIONS

A. HEMICHORDATA

- ***Hemichordates :*** *also called* ***half chordates*** *or* ***Prechordates.***
- ***Hyman*** *(1950) : Lady scientist who placed Hemichordata in non-chordata after Echinodermata.*
- ***Stomochord*** *of Hemichordates is considered as* ***little notochord.***
- *These have both* ***phosphoarginine*** *(found in echinoderms) and* ***phosphocrectine*** *(found in the vertebrates) as* ***transducers.***

B. UROCHORDATA :

- ***Herdmania (Sea squirt) :*** *Development includes tadpole larva which undergoes* ***retrogressive metamorphosis.***
- ***Ascidians*** *are sedentary urochordates, while* ***Doliolum*** *and* ***Salpa*** *are pelagic urochordates.*
- ***Pyrosoma :*** *A colonial and sedentary urochordate. It also shows* ***phosphorescense.***
- ***Oikopleura :****An appendicularian tunicate. Adult is with tail and is covered by a gelatinous house and not test. Tail is with notochord. It shows* ***neoteny or paedogenesis.***
- ***Endostyle*** *of urochordates is* ***fore-runner of thyroid gland.***
- *Excretory organ is* ***neural gland*** *which lies below the brain and is* ***homologous to pituitary gland*** *of vertebrates.*

C. CEPHALOCHORDATA :

- ***Amphioxus (lancelet) :*** *It is considered as* ***blue print of phylum Chordata*** *as have all the primary chordate characters even in the adult stage. It is called* ***lancelet*** *as its both ends are lance-like. Paired appendages are absent but median fins are present.*
- *Buccal cavity has a* ***whael-organ*** *(also called* ***Muller's organ*** *or* ***rotatory organ).***
- *Excretion is by* ***protonephridia*** *having groups of flame cells called* ***solenocytes.***
- *The oldest known cephalochordate is Pikaia whose fossils have been recorded from the Burges Shales of Canada and are of middle Cambrian period.*

D. CYCLOSTOMATA :

- *These are commonly called* ***round-mouthed animals.***
- *Tail is* ***protocercal*** *(as notochord extends straight upto the tip of tail and two lobes of caudal fin are equal).*
- *Vertebrae are represented by imperfect neural arches (****arcualia****) present surrounding the notochord.*
- *Stomach is absent. Oesophagus leads into intestine. Notochord persists throughout life.*
- ***Marsipobranchial gills :*** *When internal gills are located in pouches.*
- *Cranial nerves are 8 or 10 pairs.*
- ***Petromyzon (Sea lamprey) :*** *It is a marine,* ***sanguivorous*** *and ectoparasitic cyclostomate. It has seven pairs of gillslits. It shows* ***anadromous migration*** *(sea to fresh-water) as during spawning, both the sexes ascend rivers.*
- ***Ammocoetes*** *larva has endostyle like the protochordates, while adult has thyroid and pituitary gland.*
- ***Myxine (Hag fish or slime eel) :*** *Buccal funnel is absent but mouth is surrounded by 4 pairs of* ***oral tentacles.*** *It is called* ***borer*** *as bores into the body of fishes and eats upon their soft tissues. Trunk has only one pair of gill openings but many openings of* ***mucous glands.*** *Eyes are vestigial organs. Devolepment is direct in hag fishes.*
- ***Ostracoderms*** *are extinct agnathans.*

Table 17. Differences between Agnathostomata and Gnathostomata.

Characters	Agnathostomata	Gnathostomata
1. Mouth	Not bounded by jaws.	Jaws are present.
2. Appendages	Only unpaired appendages.	Paired appendages (fins or limbs) present.
3. Nostril	Median.	Paired.
4. Cranial nerves	8 or 10 pairs.	10 or 12 pairs.
5. Tail	Protocercal.	Heterocercal or homocercal.
6. Body temperature	Always poikilothermal.	Poikilothermal or homeothermal.
7. Notochord	Persists throughout life.	Replaced by vertebral column.
8. Internal ear	With 1 or 2 semicircular canals.	With 3 semicircular canals.
9. Examples	Sea lampreys and hag fish.	Fishes, amphibians, reptiles, birds and mammals.

2. GNATHOSTOMATA : (a) Mouth is always bounded by jaws, so called **gnathans (jawed vertebrates)**.

(b) Notochord is usually replaced by a **vertebral column.**

(c) Paired nostrils are present.

(d) Paired appendages (fins or limbs) are present.

(e) Internal ear has **three semicircular canals.**

It is divided into **two superclasses :**

SUPERCLASS PISCES

SUPERCLASS TETRAPODA

SUPERCLASS PISCES. These have following peculiar features :

(a) These are **primarily aquatic** in habitat.

(b) Locomotion is by **fins.**

(c) Respiration is **branchial** (by gills).

SUPERCLASS TETRAPODA (*tetra* = four, *podos* = feet)

These have following peculiar features :

(a) These are **primarily terrestrial.** Some are secondarily aquatic.

(b) Locomotion is by **2 pairs of limbs.**

(c) Primary respiratory organs are **lungs.** Some retain gills as respiratory organs.

SUPERCLASS PISCES

It is divided into **2 living classes** on the **basis of nature of endoskeleton :**

Chondrichthyes - Cartilage fishes (Gr. *chondron* = cartilage, *ichthyes* = fish).

Osteichthyes - Bony fishes (Gr. *osteon* = bone, *ichthyes* = fish).

CLASS CHONDRICHTHYES

Cartilaginous fishes

Characters :

1. Endoskeleton is completely **cartilaginous**. Notochord persists throughout life.

2. Habitat. All are **marine**.

3. Exoskeleton is formed of dermal **placoid scales,** also called **dermal denticles**. These help in protection and streamlining.

4. These swim in water with the help of **fins**. Paired fins are **pelvic** (for stabilizing in water) and **pectoral** (for steering and providing lift) while unpaired fins are **dorsal, ventral** and **caudal** (for propelling through the water). These have 2 **dorsal fins.** Tail fin is mostly **heterocercal** (2 unequal lobes).

5. Alimentary canal. Mouth is ventral. Teeth are modified placoid scales. Gut opens out by **cloacal aperture.** There is a **scroll valve** in intestine.

6. These show **branchial respiration**. Gill slits are 5 to 7 pairs. These are not covered by gill cover, **operculum**. **Air bladder** is absent so have to swim continuously to avoid sinking. These have **spiracles** (non-functional and internally closed gill slits) present behind the eyes.

7. Heart is always 2 **chambered.** RBCs are biconvex and nucleated.

8. Nervous system. There are **10 pairs** of cranial nerves. Cerebellum and olfactory lobes large sized as these are more dependent on equilibrium and smell.

9. Sense organs. Ear is formed of **only internal ear** having 3 semi-circular canals. Olfactory sacs (or nasal chambers) do not open in buccal cavity as internal nares are absent. **Lateral line sensory system** is present.

10. Excretory organs are **kidneys.** Cartilage fishes are **ureotelic** in excretion.

11. These are **cold-blooded** or **poikilothermal** or **ectothermic** animals.

12. Body shape. Either laterally compressed (*e.g.*, **sharks**) or dorsoventrally flattened (*e.g.*, **rays**) body.

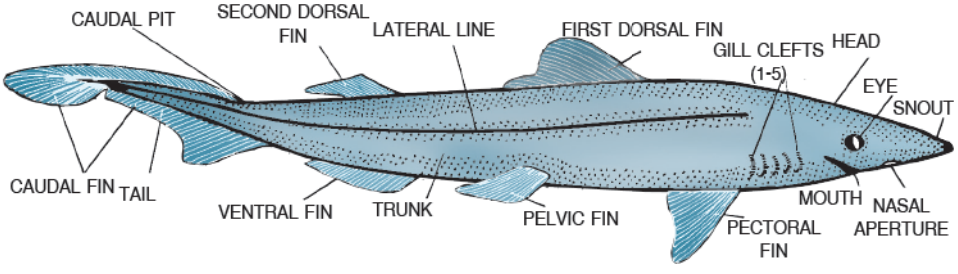
13. Sexes are always unisexual and show **sexual dimorphism.** Males have **claspers** (copulatory organs) between the pelvic fins. Fertilization is internal. Female is generally **oviparous** but some members are **viviparous** (most of sharks e.g. *Zygaena*). Development does not involve the formation of embryonic membranes *e.g.*, amnion, so these are included in **Anamniota.**

It includes about **800-1000 living species.** It includes sharks, sawfishes, rays, skates etc. Some sharks are very large sized e.g. man-eating **great white shark** about 12 metre in length.

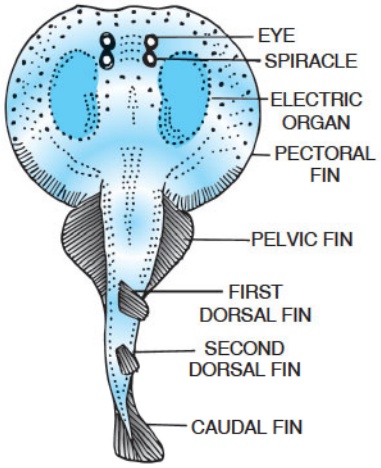
Examples (Fig. 22) : *Scoliodon* (Dog fish), *Scyllium* (Shark), *Rhinobatus* (Guitar fish), *Torpedo* (Electric ray has **electric organs**), *Trygon* (Sting ray has **poison sting**), *Pristis* (Saw fish), *Carcharodon* (Great white shark), *Rhinodon* (Whale shark), etc.

Table 18. Differences between Pisces and Tetrapods.

Characters	Pisces	Tetrapods
1. Paired appendages	Pectoral and pelvic fins.	Two pairs of pentadactyl limbs.
2. Exoskeleton	Covered by an exoskeleton of **dermal scales.**	Covered by an exoskeleton of epidermal **hair, feathers or scales**
3. Respiratory organs	Gills.	Gills or skin or lungs.
4. Habitat	Aquatic.	Primarily terrestrial.
5. Heart	2-chambered.	3 or 4 chambered.
6. Ear	Only internal ear.	Middle ear or external ear or both present.



A. *SCOLIODON*—INDIAN SHARK



B. *TORPEDO*—ELECTRIC RAY

Fig. 22. A. *Scoliodon*—Indian Shark;
B. *Torpedo*—Electric ray.

CLASS OSTEICHTHYES - BONY FISHES

(Gr. *osteon* = bone; *ichthys* = fish)

Characters :

1. Endoskeleton. Mainly **bony.**

2. Habitat. Marine or fresh-water.

3. Exoskeleton is formed of dermal **cycloid** or **ganoid** or **ctenoid** scales.

4. These swim in water with the help of **fins**. Paired fins are **pelvic and pectoral** while unpaired fins are **dorsal, ventral and caudal.** Caudal fin is usually **homocercal**. These have single dorsal fin. Tail fin is **homocercal or diphycercal.** Fins are usually supported by bony fin rays (called **lepidotrichia**).

5. Alimentary canal. Mouth is **terminal.** Gut opens out by **anus.** No scroll valve is present in intestine.

6. These have **branchial respiration**. Gill slits are 4 pairs. These are covered by gill cover, **operculum.** A **swim** or **air bladder** is usually present and acts as **hydrostatic organ** so these can stay at a particular depth without expending energy in swimming. Spiracles are absent.

7. Heart is generally **2 chambered.** RBCs are biconvex and nucleated.

8. Nervous system. There are **10 pairs** of cranial nerves. Olfactory lobes and cerebellum are small-sized.

9. The ear is formed of **only internal ear** having 3 semi-circular canals. **Olfactory sacs** generally do not open in buccal cavity. **Lateral line system** is present.

10. Excretory organs are **opisthonephric kidneys.** These are **ammonotelic.** Urinary bladder is absent.

11. These are **cold-blooded** or **poikilothermal** or **ectothermic** animals.

12. These are always **spindle-shaped** to reduce resistance during swimming.

13. Sexual dimorphism may or may not be present. **Claspers are never present.** Fertilization is internal or external. These are generally **oviparous.** Development is direct and does not include embryonic membranes like amnion, so included in **Anamniota.**

It includes about **28,000 species** of bony fishes.

Many bony fishes are used as food. **Common food fishes** of India are :

Fresh Water Food Fishes

1. *Labeo rohita* (Rohu)
2. *Catla catla* (Catla)
3. *Cirrhina mrigla* (Mrigal)
4. *Cyprio carpio*
5. *Labeo calbasu*
6. *Mystus seenghala* (Sanghara)
7. *Wallago attu* (Malli)

Marine Food Fishes

1. *Hilsa* (Hilsa)
2. *Sardinella* (Salmon)
3. *Harpodon* (Bombay duck)
4. *Stromateus* (Pomphret)

Examples (Fig. 23) : *Labeo* (Rohu), *Catla* (Katla), *Cirrhana* (Mrigal), *Clarias (Magur)*, *Hippocampus* (Sea horse), *Mystus* (Cat fish), *Exocoetus* (Flying fish), *Anabas* (Climbing perch), *Echeneis* (Sucker fish), *Ophiocephalus* (Snake headed fish), *Protopterus* (Lung fish), etc. *Betta* (Fighting fish) and *Pterophyllum* (Angel fish) are kept in aquarium.

Table 19. Differences between Sharks and Rays.

Characters	Sharks	Rays
1. Body form	Laterally compressed.	Dorsoventrally flat.
2. Gill slits	Lateral in position.	Ventral in position.
3. Pectoral fins	Distinct and not fused with the head.	Fused with the head and large sized.
4. Spiracle	Present. Small and lateral.	Always present. Large and dorsal.
5. Feeding	Surface feeder.	Bottom feeder.
6. Swimming	Fast-swimmer. *e.g., Scoliodon* (Dog fish); *Zygaena* (Hammer headed fish).	Slow swimmer by flapping action of pectoral fins. *e.g., Torpedo* (Electric ray), *Trygon* (Sting ray).

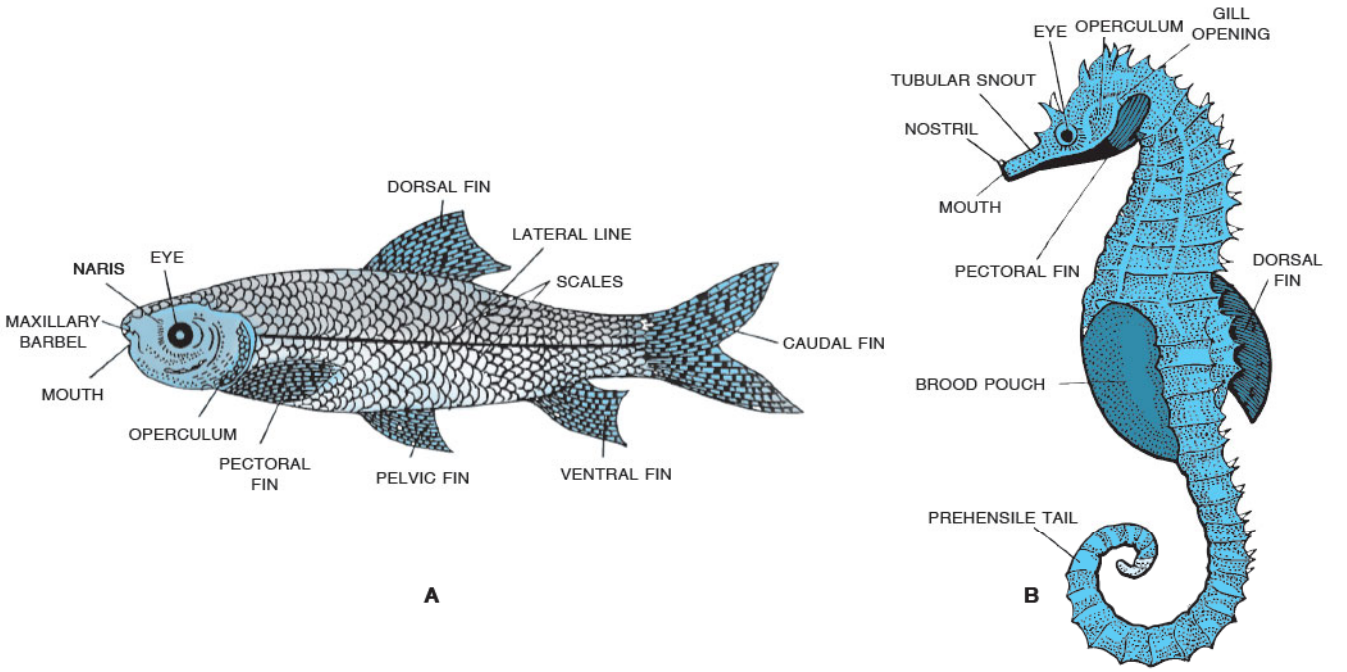


Fig. 23. A. *Labeo rohita* — Rohu; **B.** *Hippocampus* — Male Sea horse.

Table 20. Differences between Cartilage and Bony fishes.

Characters	Cartilage fishes	Bony fishes
1. **Habitat**	Always marine.	Marine or fresh-water.
2. **Exoskeleton**	Placoid scales.	Ganoid or ctenoid or cycloid scales.
3. **Endoskeleton**	Completely cartilaginous.	Mainly bony.
4. **Mouth**	Ventral.	Terminal.
5. **Gut opening**	Cloacal aperture.	Anus.
6. **Intestine**	Has a scroll valve.	Scroll valve is absent.
7. **Gill silits**	5-7 pairs. Lamellibranchs. Not covered by operculum.	4 pairs. Fillibranchs. Covered by operculum.
8. **Swim bladder**	Absent.	Present.
9. **Cerebellum**	Large sized.	Small sized
10. **Excretion**	Ureotelism.	Ammonotelism.
11. **Claspers**	Present.	Absent.
12. **Position of pelvic fins**	Posteriorly located.	Anteriorly located.
13. **Caudal fin**	Heterocercal (Asymmetrical)	Mostly homocercal (Symmetrical).
14. **Dorsal fin**	Two in number	Single.
15. **Fertilization**	Always internal	Usually external.

COMPETITION PLUS

- **Ichthyology :** Science dealing with study of fishes.
- **Pisciculture :** Rearing of fishes in artificial or natural water bodies.
- **Marine Bony fishes :** *Exocoetus* (Flying fish) and *Hippocampus* (Sea horse).
- **Other fresh-water bony fishes :** *Cyprinus, Ophiocephalus* (Channa), and *Anguilla* (Eel).
- **Gold fish** is maintained in aquaria for decorative purposes due to their variety of shapes, size and colours.
- *Hippocampus* (Sea horse fish) shows sexual dimorphism. Male has a **brood pouch** to carry fertilized eggs deposited by female. So is commonly called **pregnant male.**
- *Carcharodon* **(Great white shark) :** Most aggressive shark and is commonly called man-eating shark. Its belly is white-coloured.
- *Protopterus* **(Lung fish) :** Acts as a connecting link between **bony fishes** (Presence of fins, lateral line and operculum) and **amphibians** (has lungs and 3-chambered heart).

PRACTICE PROBLEMS – CHORDATA UPTO FISHES

83. List the diagnostic chordate characters.
84. What is notochord? Give its function.
85. What are urochordates? Give one example.
86. List two characters of Cephalochordata. Give one example.
87. Why is *Amphioxus* called typical chordate?
88. Why are urochordates and cephalochordates called Protochordates?
89. What are vertebrates? Why are these called craniates?
90. What are agnathans? Give one example?
91. Give the feeding habit of *Petromyzon?*
92. Why are hemichordates called half-chordates?
93. Give the significance of Ammocoetes larva.
94. How do pisces and tetrapods differ from each other?
95. List three common characters of fishes.
96. List three differences between cartilage fishes and bony fishes.
97. Give two differences between a shark and a ray.
98. Discuss sexual dimorphism in sea horse.
99. What are peculiar about lung fishes?
100. Which type of tail fin is found in cartilage fishes?
101. What is significance of presence of lateral line sense organs?
102. What are electric organs of electric ray? Give their function.
103. Why is *Latimeria* called a living fossil?
104. Define catadromous migration of fishes. Give one example.

ANSWERS TO PRACTICE PROBLEMS

83. Presence of **notochord;** dorsal hollow **nervous system;** gill **slits** and **tail.**
84. It is a **solid rod** on dorsal side between gut and nervous system. It acts as a **skeletal rod** to provide support.
85. Lower chordates having **notochord only in the tail** of their larva but is lost in **retrogressive metamorphosis** e.g. *Herdmania.*
86. (i) Notochord throughout the body and even in adult (ii) Many pairs of gill slits e.g. *Amphioxus* (Lancelet).
87. It has **all the basic chordate characters** even in the adult stage.
88. These are **lower groups of chordates** and lack the brain box.
89. These are the chordates in which notochord is replaced by **vertebral column** and have **brain box.**
90. These are **jawless vertebrates** e.g. *Petromyzon* (Sea-Lampry).
91. It is **sanguivorous** and feeds upon the blood of shark, etc.
92. These have certain **chordate characters** and certain **echinodermate characters.**
93. Ammocoetes larva has **lancelet-like characters** which shows cyclostomes and cephalochordates have common ancestory.
94. **Fishes** are primarily aquatic, swim with help of fins and respire with gills. **Tetrapods** are primarily terrestrial have two pairs of limbs and basically respire with lungs.
95. All the fishes are **aquatic,** respire with **gills,** locomotion by **fins,** two-chambered heart, have **lateral line sense organs,** etc.
96.

Characters	Cartilage fishes	Bony fishes
1. Habitat	Always marine.	Fresh water or marine.
2. Gill slits	5-7 pairs, no operculum.	4 pairs, with operculum.
3. Claspers	Present in male.	Absent.

97. **Shark** has laterally compressed body and gill slits on lateral sides of head. **Ray** has dorsoventrally flat body and gill slits on ventral side of head.
98. Male sea horse has a **brood pouch** to carry the eggs.
99. Lung fishes have 3-chambered heart and respire with lungs.
100. Cartilage fish has **heterocercal** tail fin (with two unequal lobes).
101. It has sensory cells (reoreceptors) to note the changes in surrounding water.
102. These are **modified muscles.** These produce an electric current (50-60 volts) for defence.
103. It is about 70 million years ago and is still living with those primitive characters.
104. It involves breeding migration of fishes **from fresh-water to sea water** and is found in *Anguilla* (Eel).

ADDITIONAL USEFUL INFORMATIONS ABOUT FISHES FOR COMPETITIVE EXAMINATIONS

A. CHONDRICHTHYES :

- *All the cartilaginous fishes are **marine,** while bony fishes are either **marine** or **fresh-water.***
- *Pectoral fins of fishes act as **balancers,** pelvic fins as **brakes** and caudal fin as **steering organ** in locomotion.*
- ***Ampullae of Lorenzini** are peculiar electroreceptors on their snout to note the thermal changes in water.*
- *Lateral line is with **neuromast organs** which have **rheoreceptors** and note electric fields in water currents. This aids in finding prey, navigation and sensing temperature.*
- *These do not have bone marrow. RBCs are produced in spleen and epigonal organ (special tissue around the gonads).*
- *These feel like sand paper due to presence of unidirectionally-oriented placoid scales.*
- *Heterocercal tail aids in locomotion.*
- ***Scoliodon (Indian shark** or **dog fish) :** A marine cartilagenous fish. Male has claspers. Female is **viviparous.** Its liver provides vitamin-A rich oil.*

- *Electric organs of Torpedo are modified muscles. These produce an electric current of 50-60 volts for defence and to paralyse the prey.*
- *Trygon (Sting ray or whip tailed ray): Dorsal fin is modified into a poisonous sting to stun the animal.*
- *Chimaera (Rabbit fish or rat fish or king of Herrings). Most advanced cartilage fish and acts as a connecting link between cartilage fishes (Cartilages only, claspers) and bony fishes (4 pairs of gill slits covered by opercula, anus and fleshy lips).*
- *Rhinodon : Largest sized (21m.) whale shark.*
- *Devonian period of Palaeozoic era is called "Age of fishes".*
- *Scales of bony fishes form a water proof coat on body for water conservation.*
- *Heterocercal tail fin is formed of upper smaller epicaudal lobe and lower larger hypocaudal lobe.*
- *Jaw suspension is hyostylic, while vertebrae are amphicoelous (centrum concave on both sides).*
- *Heart in fishes is 2-chambered, venous and branchial. It has single circulation. Aortic arches are 5 to 7 pairs.*
- *Nephrons have urea-absorbing segments so about 2.5% of urea is retained in blood to make it isotonic to sea water.*
- *Largest group of cartilage fishes is Elasmobranch.*
- *Zygaena or Sphyrna (Hammer-headed fish) : Head is produced into 2 head lobes used as a hammer to kill the prey. It is a viviparous fish.*
- *Rhinobatus is commonly called guitar fish. It is also a viviparous fish.*
- *Pristis (saw fish) : Snout is produced into saw-like rostrum with denticles and is used to kill the fishes. It is a viviparous fish.*

B. OSTEICHTHYES :

- *Largest class of Vertebrata. Oldest known fossils of bony fishes are about 420 mya.*
- *Term Osteichthyes given by Huxley (1880).*
- *Bony fishes are the most successful of all aquatic forms.*
- *Cycloid scales are circular shaped and have concentric lines of growth which indicate the age of the fish.*
- *Ganoid scales are formed of ganoin and are diamond shaped. Most primitive type of scales.*
- *Ctenoid scales are comb-like and have denticles in upper part and lines of growth in lower part. Most advanced type of scales.*
- *Homocercal is most common type of caudal fin found in most of bony fishes.*
- *Jaw suspension is autostylic (articular of lower jaw is suspended from the quadrate bone of upper jaw). Vertebrae are amphicoelous.*
- *Weberian ossicles : A chain of small sized four bones which connect the swim bladder to internal ear and help in hearing.*
- *Two groups of Osteichthyes are : Actinopterygii (Ray-finned fishes) and Sarcopterygii (Lobe-finned fishes).*
- *Largest group of bony fish includes Teleosts (Advanced ray finned fishes).*
- *Labeo (Rohu) : Adult is herbivorous but young feeds on insect larvae so help in controlling insect population.*
- *Exocoetes (Flying fish). It takes a leap in air with its powerful hypobasic tail and glides in air on the support of large sized pectoral fins (act as parachutes).*
- *Solea (Flat fish). It is an asymmetrical and laterally flat bony fish. It is pigmented on upper (right) side and unpigmented on lower side. Both eyes are on pigmented side. It is a marine and benthonic bony fish.*
- *Gambusia (Mosquito fish). It is used in biological control of mosquitoes as it is a larvaceous fish.*
- *Anguilla (Eel). It shows breeding migration from fresh-waters or estuaries to sea (Catadromous migration).*
- *Hilsa (Hilsa fish). A marine bony fish commonly found in Bay of Bengal. It shows anadromous migration.*
- *Pygmy goby (Pandaka pygmaea) is smallest bony fish, while Ocean sun fish is largest bony fish.*
- *Sail fish is fastest fish, while stone fish is most poisonous fish.*
- *Climatius is a primitive fish (became extinct about 400 million years ago in the Permean period).*
- *Pomphret is most common food fish. Catla (Theila) : Largest Indian carp.*
- *Cat fishes have sensory barbels on jaws and scaleless body e.g. Mystus (singharee = 4 pairs of sensory barbels) and Wallogonia (Mullee-2 pairs of sensory barbels).*
- *Endothermic or Homeothermic fishes: Blue fish, Tuna fish and sword fish.*
- *Syngnathus is commonly called pipe fish.*
- *Anabas (Climbing perch) : Also has labyrinthine organ as accessory respiratory organs on land so can move on land with the help of opercula and spiny fins.*
- *Diodon (Porcupine fish) : Body is covered by numerous and erectile spines. Mouth is with 2 dental plates.*
- *Tetradon (Globe fish) : Erectile spines present on ventral side of trunk. It has 4 dental plates. Most poisonous fish.*
- *Echeneis (Sucker fish or Remora) : Dorsal fin is modified into sucker. It shows commensalism with sharks, whale, etc.*
- *Lophius (Angler fish) : Found in deep sea waters. Mouth is very wide for carnivorous diet. Sexes show sexual dimorphism. Male shows sexual parasitism and is found attached on the head of female. Dorsal fin of female is spiny whose first ray bears fleshy mass, called ilicium, and is used as a bait to attract the prey.*
- *Lung fishes :*
  Protopterus = African lung fish (with two lungs); Neoceratodus = Australian lung fish (with one lung); Lepidosiren = South American lung fish (with two lungs).
- *Latimeria (Coelcanth) : A lobe-finned bony fish. It is named after Miss Latimer who recognised the significance of the fish. Called living fossil as is the representative of Palaeozoic group of bony fishes. It swims by rotation of pectoral fins and belongs to Crossopterygii group of bony fishes. It was reported in 1938 from East Coast of Africa.*
- *Placodermi are extinct fishes and have protective plates. These are considered as ancestors of amphibions.*
- *Some examples of viviparous bony fishes are : Eelpouts (Zoarces); bassfish (Sebastes); Four-eyed fish (Anableps); etc.*

SUPER-CLASS TETRAPODA

It is divided into **4 classes** on the basis of skin :

I. Class Amphibia : Skin is thin, moist, glandular, vascular and **respiratory.** It is without exoskeleton.

II. Class Reptilia : Skin is dry and **non-glandular** covered by **epidermal scales.**

III. Class Aves : Skin is dry and **non-glandular** and is covered by **feathery-exoskeleton.**

IV. Class Mammalia : Skin is **glandular** and is covered by **hairy-exoskeleton.**

(I) CLASS - AMPHIBIA

(*amphi* = both; *bios* = life)

Characters :

1. Habitat. hese are mostly **amphibious** (with double life) **animals**.

2. Skin. It is thin, moist, glandular and vascular. It is **respiratory.**

3. Exoskeleton is always **absent.**

4. These have two pairs of pentadactyl limbs, but digits have **neither nails nor claws.**

5. Endoskeleton is mainly bony. Skull is **dicondylic** (with 2 occipital condyles). First vertebra supports head and is called **atlas.** There is **no axis** vertebra. Only **single sacral vertebra** is present. True sternum is absent.

6. Mouth is wide as all are **carnivorous.** Teeth are **homodont** (similar), **polyphyodont** (in many sets) and **acrodont** (directly attached on bone). Tongue is protrusible in frogs and toads. Alimentary canal opens out by **cloacal aperture.**

7. Youngs of most of amphibians are aquatic and show **branchial respiration** while adult amphibians show **cutaneous** (skin) or **buccopharyngeal** (Buccopharyngeal cavity) or **pulmonary** (lungs) or combination of respiration (*e.g.*, in frog). Some forms (*e.g.*, *Proteus*, **newt**) *Ichthyophis* (Caecilian-limbless amphibian), etc. have gills even in adult stage (called **perennibrachiates**).

8. Heart is **3-chambered** (two auricles and one ventricle). These show **double circulation.** RBCs are oval, biconvex and nucleated.

9. Brain has **10 pairs** of cranial nerves. The cerebellum is rudimentary so these are sluggish in nature.

10. Eyes have eyelids. Ear is formed of only **internal** and **middle ear.** Middle ear has only one **ear-ossicle** called **stapes** (or **collumella auris**). Tympanum lies on the surface. Internal nares open in buccal cavity.

11. Excretory organs are **kidneys** which are **mesonephros** in adult. Excretion is generally **ureotelic.**

12. These are **ectothermic** or **poikilothermal (cold-blooded),** so **hibernate** (winter-sleep) in winter and **aestivate** (summer-sleep) in summer months.

13. Sexes are **unisexual.** Female is usually **oviparous.** Fertilization may be **external** (Frog) on **internal** (Salamander). Development is generally indirect and includes an aquatic fish-like larva (*e.g.*, **Tadpole** in frog and **axolotl** in Salamander) which undergoes metamorphosis. No embryonic membrane (Amnion) etc. is present, so amphibians are included in **Anamniota.**

The number of known amphibian species is nearly **7,000** of which nearly 90% are frogs.

Examples (Fig. 24) : *Rana* (Frog), *Bufo* (Toad), *Hyla* (Tree frog), *Salamandra* (Salamander-tailed amphibian),

Table 21. Differences between Frog and Toad.

Characters	Frog	Toad
1. **Habitat**	Amphibious.	Terrestrial.
2. **Activity**	Diurnal.	Nocturnal.
3. **Egg laying**	In a spawn (irregular mass).	In a chain.
4. **Head**	Triangular.	Semi-circular.
5. **Skin**	Thin, moist and glandular (numerous mucous glands).	Dry, rough, warty and with more poison glands for defence.
6. **Parotid glands**	Absent.	Present behind ear drums.
7. **Toes**	Webs present.	Webs absent.

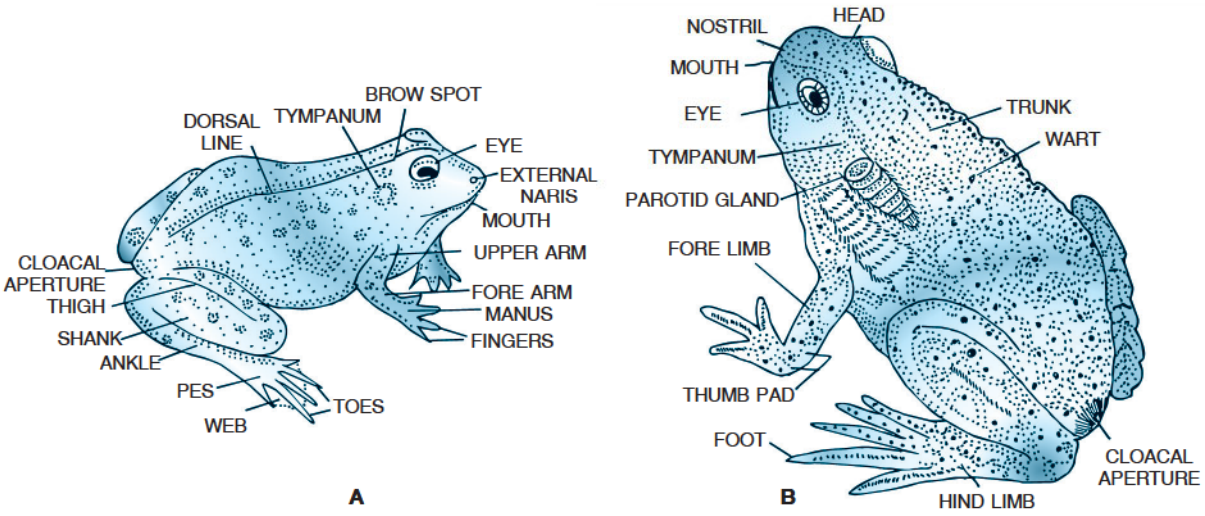


Fig. 24. A. *Rana* (Frog); **B.** *Bufo* (Toad).

ADDITIONAL USEFUL INFORMATIONS ABOUT AMPHIBIA FOR COMPETITIVE EXAMINATIONS

- *The earliest amphibians evolved in the Devonian period from sarcopterygian fish with lungs and bony-limbed fins.*
- *Study of amphibians is called* ***batrachology.***
- ***No amphibian is marine*** *as may undergo exosmosis through their thin skin.*
- *Caecilians are limbless and tailless amphibians. These belong to* ***Order Apoda.*** *These have dermal scales.*
- *Though the amphibians are* ***first terrestrial vertebrates*** *but are still* ***dependent on water*** *for their reproduction, respiration and larval development. So these have to be near water to complete their life cycle.*
- *Jaw suspension is* ***autostylic.***
- ***Proteus (Blind salamander)*** *is secondarily fresh-water amphibian.*
- *Vertebrae may be* ***procoelous*** *(2nd to 7th vertebrae) or* ***amphicoelous*** *(8th vertebra) or* ***acoelous*** *(9th vertebra of frog).*
- ***Tongue*** *is anteriorly fixed and posterior free and protrusible in frog and toad; non-protrusible in salamander but is absent in Pipa (Surinam toad).*
- *Three orders of Amphibia are :* ***Apoda*** *(includes caecilians, called* ***blind worms),*** ***Caudata or Urodela*** *(includes tailed amphibians like salamanders) and* ***Anura or Salientia*** *(tailless amphibians like frogs, toads, etc.).*
- ***Cutaneus respiration*** *is most important mode of respiration.*
- ***Carboniferous period*** *is called* ***"Age of amphibians."*** *These evolved from lobe-finned and lung-breathing bony fishes.*
- ***Rana tigrina (Frog) :*** *Sexes show sexual dimorphism. Male frog has* ***vocal sacs*** *(act as resonators to increase the pitch of call) and* ***amplexusory pads*** *(on ventral side of index finger) to grip the female.*
- *Spawn of frog has eggs in an irregular mass of jelly while that of toad has a chain of eggs.*
- ***Ichthyophis (Caecilian).*** *It is a worm-like limbless* ***(apodan)*** *and tailless fossorial amphibian. Female guards the eggs.*
- ***Alytes (Midwife toad).*** *Male carries the eggs deposited on the back of thigh.*
- ***Pipa pipa (Surinam toad).*** *Female lays the fertilized eggs in a skin pouch,* ***marsupium,*** *on its back. Hatching of tadpole larva and metamorphosis occurs in the marsupium.*
- ***Ambystoma (Tiger salamander).*** *Its development includes* ***Axolotl larva*** *which undergoes* ***neoteny or paedogenesis*** *(directly develops the gonads and starts reproduction) when abundance of food and favourable temperature.*
- ***Largest amphibian***—*Japanese giant salamander (Megalobatrachus japonicus).*
- ***Smallest amphibian***—*A microhylid frog (****Paedophryne****) from New Guninea.*
- ***Necturus (Mud puppy or water dog) :*** *Fresh-water bottom dweller of N. America. It has weak limbs and external gills. Ventricle of heart is divided by a septum.*
- ***Amphiuma (Congo-eel)***—*Has largest sized RBCs (75 μm). It has gill slits but no gills, called* ***derotrematous condition.***
- ***Rhacophorus (Flying frog)***—*Glides on the support of webs. Also has adhesive discs on digits.*
- ***Hyla (Tree frog)***—*Climbs up the tree with adhesive discs on the tips of digits. Skin is with* ***hygroscopic glands.***
- ***Salamandra (Spotted Salamander)*** *and* ***Gastrotheca*** *(marsupial frog) are Viviparous amphibians.*

(II) CLASS REPTILIA

(*L. repere* or *reptum* = to creep or crawl)

It includes **creeping** or **crawling vertebrates**

Characters :

1. Skin is dry, non-glandular and cornified for water conservation. It is covered by an exoskeleton of **epidermal scales** or bony dermal plates, called **scutes,** which form a water-proof coat on the body. Reptiles are **first true terrestrial** vertebrates.

2. These have two pairs of **pentadactyl limbs.** Each digit ends into a **claw** in lizards. Limbs of the reptiles are angled downwards which enables them to lift their body and move faster. Limbs are absent in snakes.

3. Endoskeleton is mainly formed of bones. Skull is **monocondylic.** First vertebra supports skull and is called **atlas** while second vertebra supports rotatory movements of head and is called **axis** vertebra. There are **two sacral vertebrae.** All the vertebrae are **procoelous** (Centrum is concave anteriorly and convex posteriorly). These have ribs as well as true sternum.

4. Most of reptiles are **carnivorous** so mouth is wide. Teeth are **homodont, acrodont and polyphyodont.** Alimentary canal opens out by **cloacal aperture.**

5. These show only **pulmonary** (lung) **respiration.** Larynx has no vocal cords except *gecko.*

6. Heart is structurally **3-chambered** and has **incompletely divided ventricle.** It is **4-chambered in crocodiles** and **alligators.** These have **double circulation.** RBCs are oval, biconvex and nucleated.

7. There are **12 pairs** of cranial nerves.

8. Ear is formed of internal ear, middle ear **and external auditory canal** of external ear. Middle ear has only **one ear-ossicle (stapes).**

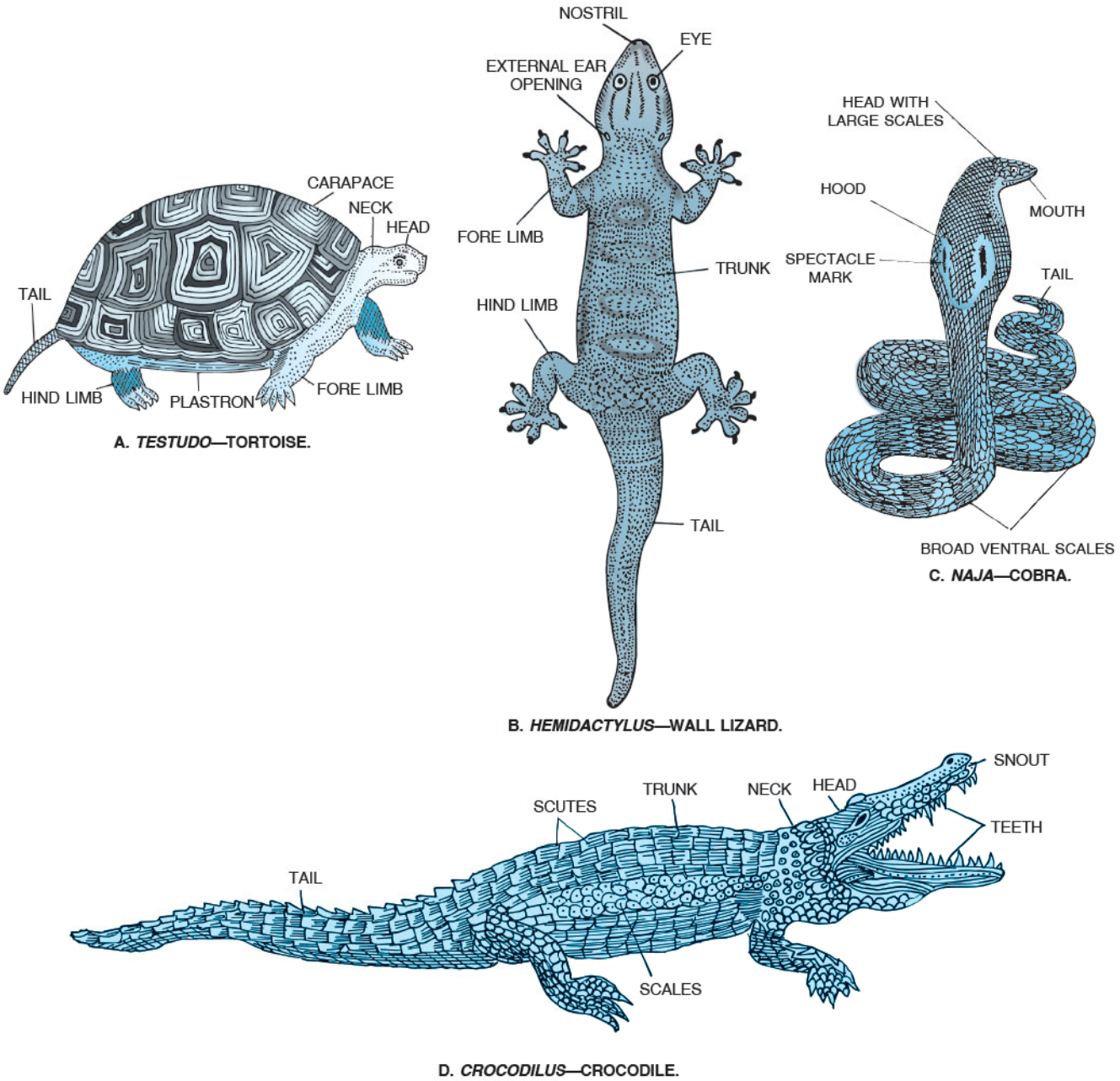
9. Kidneys are excretory organs and are **metanephros** and mostly **uricotelic**.

10. These are **poikilothermal** animals so **hibernate** in winter. These are **ectothermic** so some reptiles bask in the sun or bury themselves in the soil.

11. Sexes are unisexual and show **sexual-dimorphism.** Male lizards have copulatory organs called **hemipenes** while male crocodiles and turtles have **penis.** Fertilization is **internal.** Female is generally **oviparous** but some are **ovoviviparous** (e.g., skink lizards) or **viviparous** (*e.g.*, Sand boa, Rat snake). Egg is **polylecithal** (yolky), shelled and **cledoic** (self-sufficient). Embryo is surrounded by embryonic membranes *e.g.*, **amnion, yolk sac, allantois** and **chorion.** So are called **amniotes.** Reptiles are **first amniotic group** of the vertebrates.

Class Reptilia comprises more than **10,000 living species (July, 2018).**

Examples (Fig. 25) : *Hemidactylus* (Wall lizard), *Chelone* (Turtle), *Testudo* (Tortoise), *Chamaeleon* (Tree lizard), *Calotes* (Garden lizard), *Naja* (Cobra), *Bungarus* (Krait), *Vipera* (Viper), *Crocodilus* (Crocodile), *Aligator* (Aligator), etc.



A. *TESTUDO*—TORTOISE.

B. *HEMIDACTYLUS*—WALL LIZARD.

C. *NAJA*—COBRA.

D. *CROCODILUS*—CROCODILE.

Fig. 25. A. *Testudo* (Tortoise); **B.** *Hemidactylus* (Wall lizard); **C.** *Naja* (Cobra); **D.** *Crocodilus* (Crocodile).

Table 22. Differences between Lizards and Snakes.

Characters	Lizards	Snakes
1. Limbs	Generally two pairs of limbs.	Limbs absent.
2. Scales	Of uniform size.	Differentiated into plates and shields.
3. Eye-lids	Movable.	Immovable. Eye covered by transparent scale.
4. Nictitating membrane	Present.	Absent.
5. Tympanum	Present.	Absent. Insensitive to air borne sound.
6. Tongue	Not bifid.	Protrusible and bifid.
7. Lungs	Both lungs are equally developed.	Left lung is reduced.
8. Urinary bladder	Present.	Absent.
9. Jaw bones	Fixed	Movable

PRACTICE PROBLEMS – AMPHIBIA AND REPTILIA

105. Discuss the nature of skin in the amphibians and reptiles.
106. Why is frog called an amphibious animal?
107. Differentiate between the nature of heart in an amphibian and a reptile.
108. What is peculiar about the development of frog?
109. Why are the fishes and amphibians called anamniotes?
110. What are amplexusory pads? Give their function.
111. Discuss sexual dimorphism in frog.
112. List two differences between frog and toad.
113. Why is there no marine amphibian?
114. What are caecilians?
115. Define paedogenesis.
116. List two terrestrial adaptations in the reptiles.
117. What is peculiar about the type of heart in the crocodiles?
118. What is tortoise shell?
119. List two differences between turtles and tortoise.
120. What are hemipenes? Give their function.
121. Define autotomy. What is its significance?
122. Why does wall lizard not fall even while running on wall?
123. List two differences between a lizard and a snake.
124. Which period is called "Age of Reptiles"?
125. List two mammalian characters of crocodiles.

ANSWERS TO PRACTICE PROBLEMS

105. It is thin, moist and respiratory in amphibians but is dry, non-glandular and scaly in reptiles.
106. It can live both in water and on land.
107. In both, heart is 3-chambered with 2 auricles and one ventricle. Ventricle is **unpartitioned** in the amphibians while is **incompletely partitioned** in the reptiles.
108. Presence of a **fish-like tadpole** larva in the life cycle.
109. As these have **no embryonic membranes** (like amnion, chorion, etc.) in their development.
110. These are swellings on the **index fingers** of only male frog. These help in **copulation** or **amplexus.**
111. Male frog has amplexusory pads, vocal sacs, more stronger forelimbs, etc.
112. **Frog** is amphibious in habitat, has respiratory skin and also webs between toes. **Toad** is terrestrial in habitat, has dry and warty skin but no webs between toes.
113. As their skin is thin, amphibian will die in sea water due to loss of water by exosmosis.
114. These are **limbless amphibians.**
115. Also called **neoteny.** In this, larva develops the gonads without undergoing metamorphosis and starts reproduction.
116. (i) Epidermal scales forming exoskeleton. (ii) shelled and cledoic egg.
117. Heart is **4**-chambered and teeth are heterodont and thecodont (in sockets).
118. It is formed of 2 pieces : Dorsal **carapace** and ventral **plastron.** During defence, body can be with- drawn into it.
119. **Turtle** is aquatic in which limbs are modified into paddles (e.g. sea turtle), **Tortoise** is amphibious in which digits are clawed.
120. These are **copulatory organs** of lizards and snakes. These transfer the gametes into female genital tract.
121. **Shedding of body parts** in self-defence is called autotomy e.g. tail in wall lizard. It is used to defend from the predators.
122. Due to **vacuum created** between the lamellae of adhesive pads of digits of limbs.
123. A **lizard** has limbs and ear drum which are absent from a snake.
124. **Jurassic period** of Mesozoic era.
125. Four-chambered heart; heterodont and thecodont teeth.

ADDITIONAL USEFUL INFORMATIONS ABOUT REPTILIA FOR COMPETITIVE EXAMINATIONS

- ***Herpetology :*** *Study of reptiles.* ● ***Ophiology :*** *Study of snakes.* ● ***Saurology :*** *Study of lizards.*
- ***Jurassic period*** *of mesozoic era is called "**Age of dinosaurs**"* ● *Mesozoic era is called "**Age of reptiles**".*
- *Only glands present in lizards are **femoral glands** on the thigh of male lizards.*
- *Dinosaurs became extinct in Cretaceous period of Mesozoic era.*
- *Reptiles are not found in cold climate due to their poikilothermal nature.*
- *Snakes have both scales and scutes, whereas turtles and crocodiles have scutes.*
- ***Jacobsons organs*** *are additional smelling organs of reptiles and are present in the roof of buccal cavity.*
- ***Turtles*** *are aquatic reptiles while **Testudo** (Tortoise) is an amphibious reptile. In both turtles and tortoises, the body is covered by a **tortoise shell** which is formed of upper **carapace** and lower **plastron.***

- *Most of reptiles lack the secondary palate that allows breathing while chewing and swallowing. But the turtles have a partial secondary palate, while crocodiles have a bony secondary palate like mammals.*
- ***Hemidactylus (wall lizard)** does not fall due to presence of **adhesive lamellae** on ventral side of digits which work on vaccum principle. It can lose its tail in self defence **(autotomy)** which can be regenerated.*
- ***Heteromorphosis :** When regenerated organ is different e.g. new tail of wall lizard has no tail vertebrae.*
- ***King cobra** makes its own nest, cobras may be **binocellate** or **monocellate** or **non-cellate. Hood** is the expanded neck of cobra due to presence of movable ribs of neck vertebrae.*
- ***Temporal vacuoties** of skull form the basis of classification of reptiles.*
- *Reptiles are first vertebrates to have ribs which are **monoheaded.***
- ***Leather back sea turtle** can regulate its body temperature to some degree.*
- *Reptiles are closest living relatives of both modern birds and mammals.*
- ***Anapsids** are reptiles with no temporal vacuities in the skull e.g. turtles and tortoise, while **diapsids** have two temporal vacuoties on each side of skull e.g. lizards and snakes.*
- *Only herbivorous reptiles are turtles and iguanas.*
- ***Cotylosaurs** are considered to be the "**stem reptiles**" and closely resemble the labyrinthodont amphibians.*
- ***Typhlina brahmina : Smallest snake** of India and in the life cycle females show **parthenogenesis.***
- *Poisonous snakes form only **10%** of snakes.*
- ***Some viviparous snakes : Hydrus (Sea snake);** Vipera russelli; **Russel's viper; Rat snake;** etc.*
- ***Rattle :** A chain of a few scales at the posterior end of tail of rattle snake and is used to produce a rattling sound.*
- ***Largest snake : Anaconda** (Eunectes murinus).*
- ***Seymouria :** A "**missing link**" between amphibians and reptiles. It lived during **Permian period** of palaeozoic era.*
- ***Calotes (Garden lizard or blood sucker) :** When disturbed, it raises head and neck and blood is forced so that head becomes red coloured.*
- ***Chamaeleon (Chamaeleon) :** It is characterized by helmet-like head, circular pupil, absence of ear drums, syndactyly in digits, prehensile tail, long and protrusible tongue and protective colouration **(metachrosis).***
- ***Phrynosoma (Horned toad).** A desert lizard with spines on body and spikes on head. Skin is with **hygroscopic glands** and can absorb moisture from dew drops.*
- ***Varanus komodensis :** Largest living lizard (3 metres) found in Komodo islands of Malaysia.*
- ***Common poisonous snakes** are **Bungarus (Krait), Vipera (Pit viper), Hydrus (Sea snake), Naja (Cobra).***
- ***Draco** is flying lizard and glides on the skin folds called **patagia** supported by ribs. Neck has hooks and a gular pouch for climbing.*
- ***Heloderma (Gila monster)** is the only poisonous lizard with neurotoxin.*
- ***Sphenodon (Tautara) : A **living fossil** reptile of **New Zealand.** It has 3rd eye, amphicoelous vertebrae.*
- ***Mammalian characters of crocodiles :***
  - ☞ *Four chambered heart.*
  - ☞ *Secondary palate is fully formed.*
  - ☞ *Internal nares open in pharynx.*
  - ☞ *Single penis as copulatory organ.*
  - ☞ *Cochlea in internal ear.*
  - ☞ *Heterodont and thecodont teeth.*
  - ☞ *Diaphragm-like partition.*
- ***Crocodile** is largest amphibious reptile. It is **piscivorous.** Its snout is short and broad while teeth are heterodont and thecodont.*
- ***Gavialis (Gharial)** differs from crocodile in having long tubular snout which forms pot-like enlargement in the male.*
- *Snakes with **neurotoxic venom : Bungarus (Krait); Naja (Cobra); Hydrus (Sea snake).***
- *Snake with **haemolytic venom. Vipera (Pit viper).***
- ***Limbless lizards :** ☞ **Anguis fragilis** = Blind worm. ☞ **Ophiosaurus** = Glass snake.*
- *Poisonous snakes have poisonous teeths called **fangs** (modified maxillary teeth) and **poison glands** (modified salivary glands). Snake poison is called **venom** and can be neutralised by **antivenine injection.***
- ***Dinosaurs** (means **terrible reptiles**) were giant-sized fossilized reptiles of Mesozoic era e.g., **Brontosaurus (Thunder lizard**—a herbivorous dinosaur) and **Tyrannosaurus (Tyrant-lizard** — a carnivorous dinosaur and commonly called **king of Dinosaurs).***
- *With reference to excretion, crocodiles are **ammonotelic**, turtles are **ureotelic** while lizards are **uricotelic**.*
- *Advantage of ectothermism is that these have to eat much less than homeothermic birds and mammals.*

III. CLASS AVES (*avis* = Bird)

Characters :

1. Body shape is boat-shaped to reduce resistance in air during flight. Body is divided into **4 parts :** Head, neck (long sized), trunk and tail (very reduced).

2. These are **feathered-bipeds.** Skin is dry and non-glandular except **oil** or **uropygial** or **preening gland** on tail (except ostrich and parrot) and is further covered by a **feathery-exoskeleton** which conserves body heat.

3. These have **two pairs** of **pentadactyl limbs.** Fore limbs are modified into **wings.** Fingers are three in number but without claws. Hind limbs are modified for perching or walking or swimming or running. Toes are usually four in number.

4. Endoskeleton is mainly formed of bones. Most birds have light weight and rigid endoskeleton for flight. Skull is **monocondylic.** Long bones are **pneumatic** (with air cavities) to reduce body weight. Sacral vertebrae are many and fuse to form **sacrum.** Tail vertebrae fused to form **pygostyle.** Vertebrae are **heterocoelous.** Ribs are double headed with **uncinate processes. Sternum** (chest-bone) is keeled for attachment of flight muscles.

Tibiotarsus (tibia + tarsals) and **tarsometatarsus** (tarsals + metatarsals) are formed in hind limbs. **Carpometacarpus** is formed in forelimbs.

5. Mouth is always bounded by a **beak** (modified jaws) covered by a horny sheath, **rhamphotheca.** Birds are **edentulous** (no teeth). Food-storing **crop** and food-masticating **gizzard** are present. Alimentary canal opens out by **cloacal aperture.**

6. Birds show only **pulmonary respiration** (with lungs). Lungs have **air sacs** which help in **double respiration** and also act as **internal cooling agents.** Sound producing organ is **syrinx** (at the base of trachea).

7. Heart is proportionately large sized. It is **4-chambered. Right aortic arch** and pulmonary arch are present. RBCs are oval, biconvex and nucleated.

8. Brain has **12 pairs** of cranial nerves. Optic lobes (sight) and cerebellum (equilibrium) are large sized as these are more dependent upon sight and equilibrium.

9. Internal ear has cochlea but is not coiled. There is single ear-ossicle **(stapes)** in middle ear. Eyes have **double accommodation power.**

10. Excretory organs are **metanephric kidneys.** Each kidney is **trilobed.** Excretion is **uricotelic.** Urinary bladder is absent.

11. Sexes are **unisexual** and generally show **sexual-dimorphism.** Fertilization is **internal** by cloacal apposition. Female always **oviparous.** Right ovary and oviduct are lost or vestigial in female. Egg is **polylecithal, cledoic** and shelled. Embryonic membranes (*e.g.*, **amnion**) are formed during development. Development includes either **precocial young** (i.e. young is active and motile) or **altricial young** (i.e. young is helpless or naked).

12. These are **homeothermal** or **warm-blooded** (constant body temperature) animals. Body temperature is over 100°F due to **endothermic** sources and high metabolic rate.

It includes about **9,000 living species** of birds.

Examples (Fig. 26) : *Corvus* (Crow), *Columba* (Pigeon), *Psittacula* (Parrot), *Struthio* (Ostrich), *Pavo* (Peacock), *Aptenodytes* (Penguin), *Neophron* (Vulture), *Anas* (Duck), *Milvus* (Kite), *Tyto* (Owl), *Eudynamis* (Koel), etc.

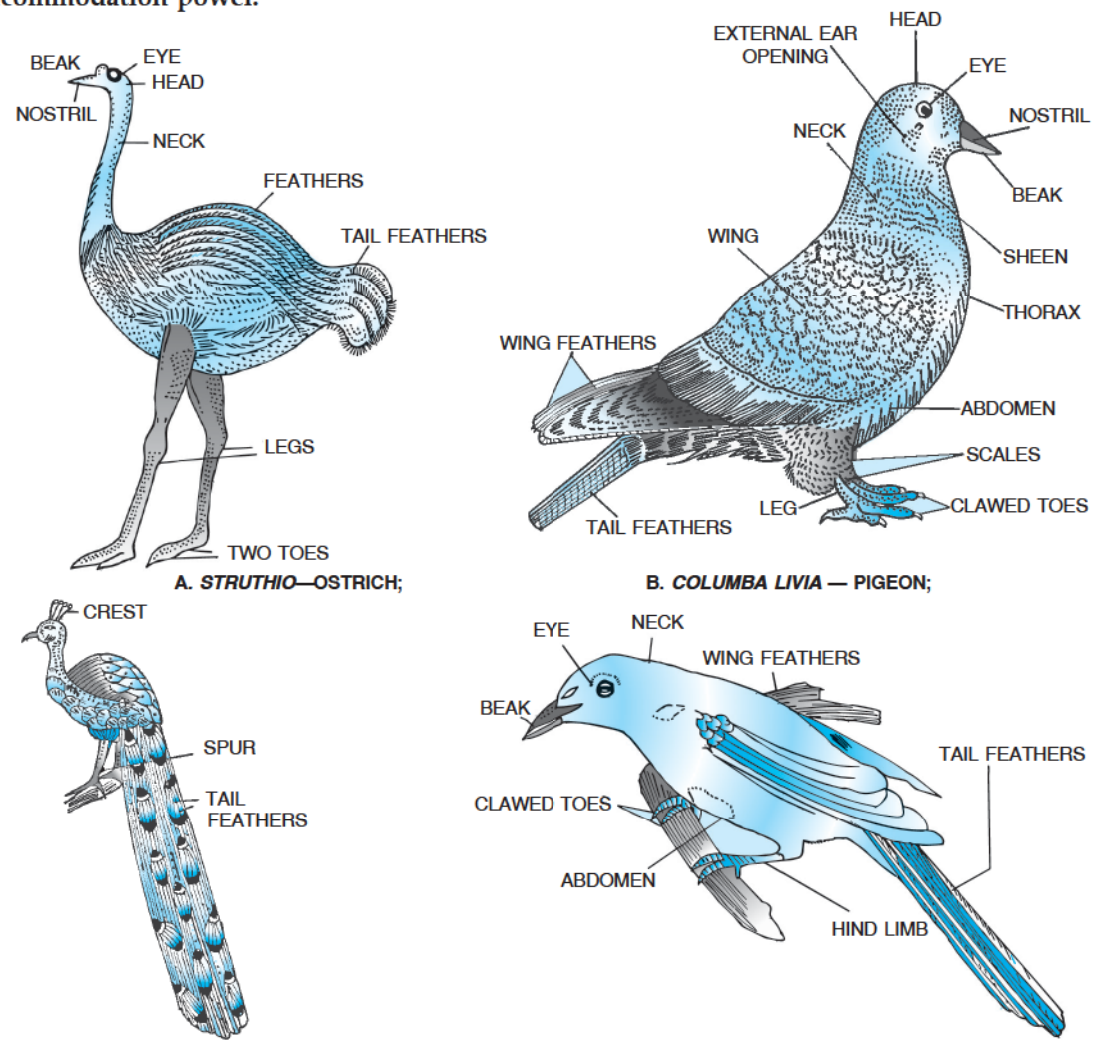


Fig. 26. A. *Struthio*—Ostrich; **B.** *Columba* (Pigeon); **C.** *Pavo* (Peacock); **D.** *Eudynamis* (Koel).

FLIGHT ADAPTATIONS IN BIRDS

1. Body is **streamlined** to reduce air resistance.
2. Fore limbs are modified into **wings**.
3. Wings have long **quill feathers (Remiges)** to increase the efficiency of beating of wings.
4. Well developed **flight muscles (pectoralis major** and **pectoralis minor**).

5. Presence of **pneumatic bones** to reduce the body weight.

6. Absence of teeth, gall bladder, urinary bladder, right ovary and oviduct etc. to reduce body weight.

7. Presence of **keeled-sternum.**

8. Tail feathers **(rectrices)** form a **stearing** (direction providing) **apparatus.**

9. **High metabolic rate** to provide energy.

10. Fusion of bones *e.g.*, **carpometacarpus, tibiotarsus** and **tarsometatarsus** to strengthen the skeleton .

11. Presence of **air-sacs** which help in **double respiration.**

ADDITIONAL USEFUL INFORMATIONS ABOUT AVES FOR COMPETITIVE EXAMINATIONS

- *Ornithology : Study of birds.* ● *Nidology : Study of nests.* ● *Phenology : Mogration of birds.*
- *Archaeopteryx (Flying lizard) : Extinct bird of Jurassic period. A missing link between reptiles (teeth, free tail vertebrae and claws on digits) and birds (rounded cranium, feathers).*
- *Birds are the most beautiful among the animals. They show courtship, nest building, parental care, migration and territorial behaviour.*
- *T.H. Huxley : Birds are glorified reptiles (Birds have reptilian ancestory).*
- *Caudal vertebrae fused to form pygostyle homologous to coccyx of man.*
- *A V-shaped furcula or wish bone or merry thought present. It is formed of 2 clavicles and an interclavicle.*
- *Cloaca is with a lymphoid mass called cloacal thymus or Bursa Fabricus. It is site of differentiation of T-lymphocytes.*
- *Penguins have double trachea.* ● *Bird having penis : Struthio (ostrich) and Geese.*
- *Pigeon's milk : Secretion of crop glands of crop of some female birds. It is regurgitated and fed to youngone.*
- *In owls, pupil size can be increased tremendously and have more rods, have keenest eye sight at night.*
- *Guano : Phosphorus-rich faecal matter of certain sea birds.*
- *Quil feathers are largest sized and are present on wings (called remiges) and tail (called rectrices and act as steering apparatus).*
- *Young is either nidifugous or precocial (feathered, able to walk and feed e.g. fowls) or nidiculous or altricial (naked, helpless and dependent e.g. sparrow, dove, etc.)*
- *Feathers help not only in flight but also in a number of other functions like warmth, protection, attracting mates, etc.*
- *Air flow in the birds is unidirectional while it is bidirectional in the mammals. Birds also have cross-current exchange system with the blood.*
- *Ratitae or Palaeognathae includes running birds e.g. Struthio, Apteryx, Emu, etc.*
- *Fowls, peafowls and pheasants are game birds and have a bony spur for fighting.*
- *Parrots show both syndactyly and zygodactyly.*
- *Rhea americana (South American ostrich) : Only bird with urinary bladder.*
- *Struthio (Ostrich) is largest flightless bird found in deserts of Africa and Arabia. It is cursorial and polygamous. Female lays largest sized eggs which are incubated by only male. These have solid bones in the legs for powerful kicks.*
- *Cassuarius (Cassowary) is the flightless bird of Australia.*
- *Milvus (kite) and Falco (Baj) are diurnal birds of prey. These have strongly clawed toes and hooked beak to capture and tear the prey. Eagle has keenest day vision.*
- *Pavo (Peafowl) shows sexual dimorphism. Male has a crest on head, brightly–coloured sheen, long ocellated tail feathers and a bony spur on leg (for fighting). Male is polygamous and shows peculiar dance during breeding.*
- *Anas (Duck) is a semi-aquatic bird having webs between the toes and flat beak to search food in mud.*
- *Eudynamis (Koel) shows sexual dimorphism. Male is shining black-coloured while female is brown-coloured having white spots. It shows nest parasitism of crow. Male is famous for its sweet voice during mango season.*
- *Apteryx (Kiwi) : Flightless bird of New Zealand. Each foot has four toes.*
- *Penguins : Flightless birds of Antarctica (South pole) and are characterized by flipper-like forelimbs; toes 4 in number, webbed and all forward-directed; thick fat layer (Blubber) beneath the skin. These have heavy bones filled with bone narrow to survive in freezing home range.*
- *Choriotis nigriceps (Great Indian Bustard) : A highly endangered bird found in semi-arid areas of Rajasthan.*
- *Smallest bird of world (America) : Humming bird. Smallest bird of India : Sun-bird.*
- *Peacock (Pavo cristatus) : National bird of India* ● *Monal : State bird of Himachal Pradesh.*
- *Longest migratory bird : Arctic tern (40,000 km. in a year).*
- *Dr. Salim Ali : Bird man of India, a famous Indian ornithologist. He wrote his autobiography "Fall of a sparrow".*
- *Micropodus (Swift) : Fastest bird.*
- *Flightless birds :* ☞ *Struthio : Ostrich of Africa and Arabia.* ☞ *Rhea : Ostrich of South America.* ☞ *Penguins : of Antarctica.* ☞ *Casaurius : Cassowary of Australia.* ☞ *Emu : of Australia (Second largest bird)* ☞ *Apteryx : Kiwi ; National bird of New Zealand.*

IV. CLASS MAMMALIA

(GK. *mammae* = milk glands)

Characters :

1. Exoskeleton. They are **hairy-quadrupeds.**

2. These have two pairs of **pentadactyl limbs.** Digits have **nails** or **claws** or **hoofs.** Limbs are variously modified to adapt different types of locomotion like walking (*e.g.* in man), running (*e.g.* ungulates, rodents, carnivores, etc), burrowing (*e.g.* lagomorphs), swimming (e.g. whales) and flying (*e.g.* bats, flying lemur, etc.)

3. Skin is glandular and has two types of glands: **oil (sebaceous) glands** and **sweat (sudoriferous) glands.**

4. Endoskeleton is mainly bony. Skull is **dicondylic.** Lower jaw is formed of single **dentary** or **mandibular bone.** Neck generally has **seven cervical vertebrae.** All the vertebrae are **amphiplatyan** (centrum flat on both sides).

5. Coelom is divided into anterior thoracic cavity and posterior abdominal cavity by **diaphragm.**

6. Mouth is bounded by two **movable lips,** teeth are **heterodont** (different types), **thecodont** (in sockets of jaw bones) and generally **diphyodont** (presence of two sets of teeth. Gut opens out by **anus.**

7. These show only **pulmonary** (lung) **respiration.** Sound producing organ is **larynx** which is supported by four cartilages. Glottis can be closed by **epiglottis.**

8. Heart is **four-chambered.** RBCs are **biconcave and denucleated** except camel and llama. Mammals lack the renal portal system.

9. Brain has **12 pairs** of cranial nerves. **Optic quadrigemina** (4 optic lobes) and **corpus callosum** are found only in brain of mammals.

10. Internal ear has **coiled cochlea** with hearing apparatus called **organ of Corti,** middle ear has **3 ear ossicles** (stapes, incus and malleus) and external ear has also **pinna.** Internal nares open in pharynx.

11. Kidneys are **bean-shaped.** Excretion is **ureotelic.**

12. Sexes are **unisexual** and generally show **sexual-dimorphism.** Male has copulatory organ called **penis.** Testes lie in skin pouches, **scrotal sacs.** Eggs are generally **microlecithal** (little yolk). Fertilization is **internal.** Female is generally **viviparous** except **Prototherians** (egg-laying mammals). Embryo is surrounded by **amnion** so placed in **Amniota.** They show high degree of **parental care.** Female suckles the young on her milk for some time. Milk is produced by **mammary glands** which is the most peculiar feature of the mammals.

13. These are **homeothermal** (warm-blooded) or **endothermic animals,** so have high metabolic rate.

14. Mammals live in nearly every available habitat. They are dominant animals because of well developed brain. There are about **5,416 living species** of mammals.

Mammals are most adapted vertebrates so are capable to live in variety of habitats (*e.g.* polar bear in polar ice caps), deserts (*e.g.* kangaroo rats), mountains (*e.g.* yak), forests (*e.g.* apes), grasslands (*e.g.* deer, lion, tiger, etc), aerial (*e.g.* bats), aquatic (*e.g.* whales, seals, etc.) and burrows (*e.g.* rabbits, rodents, etc).

Class Mammalia includes about **4,400 living species.**

Important groups of Class Mammalia :

A. Prototherians (Egg-laying mammals)

B. Metatherians (Pouched mammals)

C. Eutherians (True mammals)

A. Prototherians (Monotremes)

1. These are **primitive mammals** with some reptilian characters.

2. These act as **connecting links** between **reptiles and mammals.** These resemble the reptiles in presence of well developed coracoid, cloaca and cledoic (shelled and polylecithal) eggs. These resemble the mammals in having hair, mammary glands (without nipples) and diaphragm. These lack certain typical mammalian characters like pinna in external ear; nipples of mammary glands; corpus callosum in brain; placenta, etc.

3. These are confined to **Australian region.**

Examples : *Ornithorhynchus* (Duck-billed platypus) **(Fig. 27A)**, Spiny ant eater.

B. Metatherians (Pouched mammals)

1. These are pouched (with **marsupium, so called marsupials**) and **viviparous.** Imperfectly developed **mammary foetus** is nursed by the female in the marsupium.

2. Uterus and vagina are **double.**

3. Generally have **yolk-sac placenta.**

4. Mammary glands and **nipples** present.

5. Anus and urinogenital apertures are controlled by a **common sphincter.**

Example : *Macropus* **(Kangaroo – Fig. 27 B),** *Didelphis* **(Opossum).**

C. Eutherians (True placental mammals)

1. These have **true placenta.** Intra-uterine period is long and birth occurs at an advanced stage.

2. Uteri fuse to form a **common vagina.**

3. Separate openings of alimentary canal and urinogenital system.

4. Corpus callosum present.

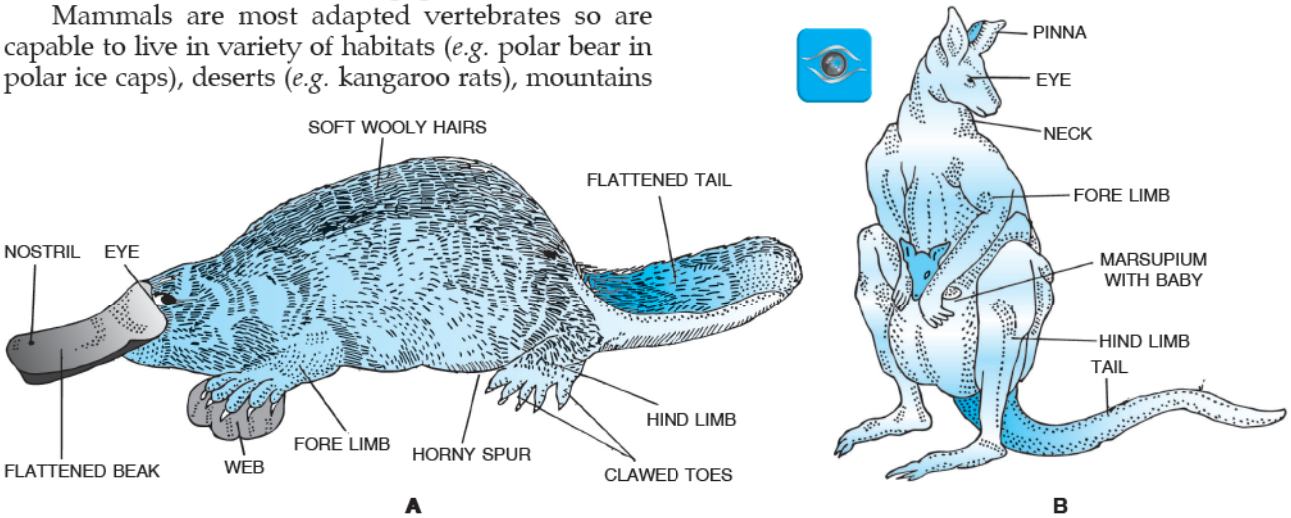


Fig. 27. A. *Ornithorhynchus*–Duck-billed platypus; **B.** *Macropus* - Kangaroo.

Table 23. Differences between Prototherians, Metatherians and Eutherians.

Characters	Prototherians	Metatherians	Eutherians
1. Mode of breeding	Oviparity.	Viviparity.	Viviparity.
2. Pinna	Absent.	Present.	Present.
3. Nipples (mammae)	Absent.	Present.	Present.
4. Marsupium	Absent.	Present.	Absent.
5. Gut and genital openings	Common aperture of cloaca.	Separate apertures but controlled by common sphincter.	Separate openings.
6. Corpus callosum	Absent or weakly developed.	Absent or weakly developed.	Well developed.
7. Testes	Abdominal in position so no scrotum.	Located in scrotum infront of penis.	Located in scrotum present behind penis.
8. Nature of egg	Macrolecithal and shelled.	Microlecithal but not shelled.	Microlecithal but not shelled.
9. Placenta	Not formed.	Yolk sac placenta.	Well developed placenta.
10. Examples	Platypus and spiny ant eater.	Kangaroos.	Bats, whales, ruminants, rodents, primates, etc.

5. Mammary glands and nipples present.

Eutherians are divided into following groups :

I. Insectivorous line *e.g.* insectivores, bats and primates.

II. Rodents and Lagomorphs (Rabbits) include gnawing mammals.

III. Whales, dolphins and porpoises — aquatic mammals.

IV. Elephants, carnivores and ungulates.

1. Insectivores. These have long and tapering snout and are fossorial, nocturnal and insectivorous. These have many pairs of **teats.** Testes are abdominal. Feet are plantigrade. *e.g., Erinaceus* **(Hedgehog);** *Talpa* **(mole);** *Echinosorex* **(shrew),** etc.

2. Chiropterans

(*i*) These are **nocturnal flying mammals.**

(*ii*) Flight organs are **patagia**—Skin folds supported by fore limbs except first digit. These fly on the **radar** or **Echo-location principle** using supersonic sounds.

(*iii*) These are either **insectivorous** or **frugivorous.**

(*iv*) Bones are **pneumatic.**

(*v*) **Keeled-sternum.**

(*vi*) Bats cannot stand erect because their legs are weak and knees are turned backward.

(*vii*) Only one pair of teats on the thorax as produce only one or two youngones at a time.

Examples : *Pteropus* (Flying fox), *Desmodus* (Vampire bat), etc.

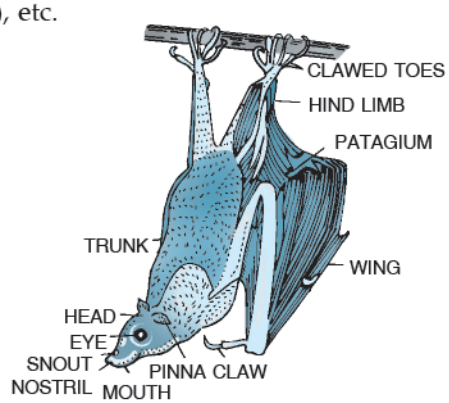


Fig. 28. *Pteropus*—Flying fox.

3. Primates (L. *primus* = of first rank)

(*i*) Cerebrum is most developed, so these are **most intelligent mammals** so are **"foremost in rank".**

(*ii*) **Binocular vision**

(*iii*) Pollex opposable to fingers, so **grasping power** in hands.

(*iv*) **Only one pair of teats** on ventral thoracic wall.

(*v*) **One or two youngs** are borne.

(*vi*) Generally **nails** are present on the tip of digits.

(*vii*) **Plantigrade** (on soles and palm) locomotion.

Examples : *Macaca* **(Rhesus monkey);** *Loris* **(Lemur);** *Presbytis* **(Langur);** *Hyalobates* **(Gibbon);** *Pan* **(Chimpanjee);** *Gorilla, Homo sapiens* **(Man)** etc.

Among the primates, **lemurs** (with long non-prehensile tail), **tarsiers** (with a group of hair at the end of tail) **loris** (tailless primate) are collectively called **prosimians** while monkeys, apes and man are collectively called **simians. Ape found in India is Gibbon** (*Hyalobates*) while *Orangutan* in Indonesia and Gorilla and Chimpanzee in Africa. **Largest ape is gorilla while most intelligent ape is chimpanzee.**

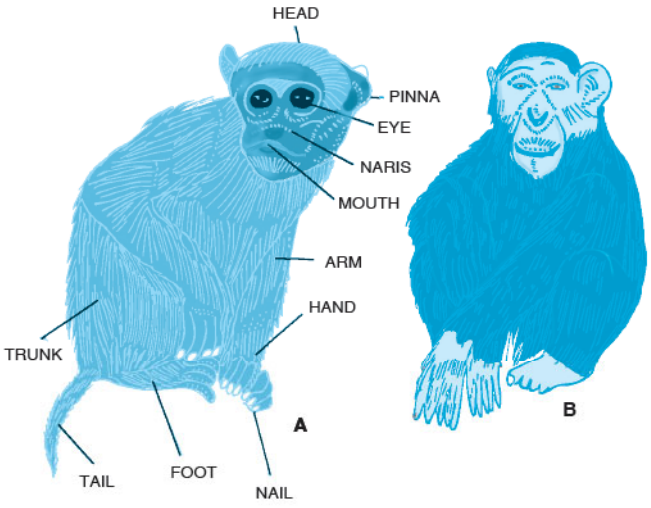


Fig. 29. Primates. **A.** *Macaca*—Rhesus monkey. **B.** *Pan*—Chimpanzee

4. Rodents (L. *rodo* = gnaw)

(*i*) These are **cursorial** and **digitigrade.** Digits are always clawed.

(*ii*) **Incisors** (One pair in each jaw) are chisel-shaped but canines are absent.

(*iii*) A toothless space called **diastemma** is present between incisors and premolars.

(*iv*) **Gnawing** mammals.

(*v*) **Many teats** on ventral side of trunk in female. Prolific breeder.

(*vi*) These are **mostly fossorial.**

Examples : *Hystrix* **— Porcupine;** *Rattus* **(Rat);** *Funambulus* **(Squirrel),** *Mus* **(Mouse) etc.**

5. Lagomorphs (Gr. *lagos* = hare; *morphe* = form)

These resemble the rodents in all the characters except that these have **two pairs of incisors in the upper jaw** and one pair in the lower jaw. Hind limbs are larger than the fore limbs for leaping.

Example : *Oryctolagus* **(Rabbit),** *Lepus* **(Hare),** etc.

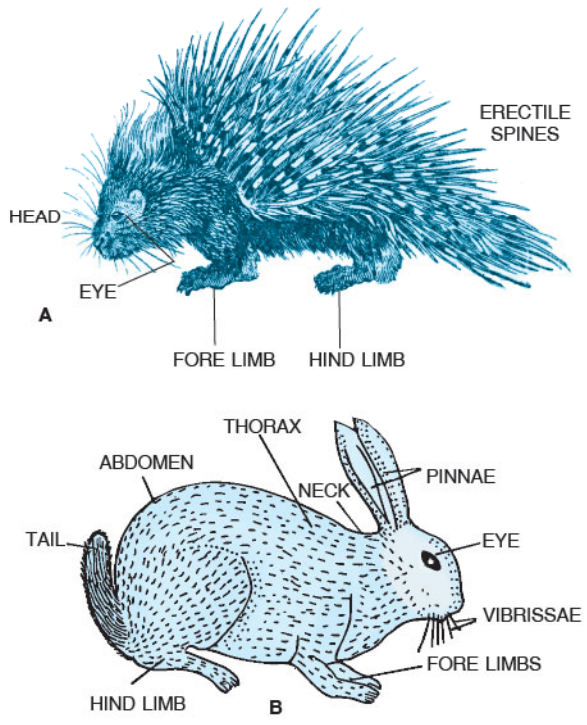


Fig. 30. A. *Hystrix*—Porcupine; **B.** *Oryctolagus*— Rabbit

6. Cetaceans (L. *cetus* = whale)

(*i*) These are **aquatic mammals.**

(*ii*) These have **streamlined body** but neck is absent.

(*iii*) Fore limbs are modified into **flippers** (used as paddles) while hind limbs are absent.

(*iv*) A well developed **fatty blubber** beneath the skin to conserve body heat. It also reduces the specific gravity.

(*v*) Loss of hair, sweat and oil glands.

(*vi*) Tail modified to act as **steering organ** in water and forms two lobes called **flukes.**

Example : *Balaenoptera* **(Whale),** *Delphinus* **(Dolphin),** etc.

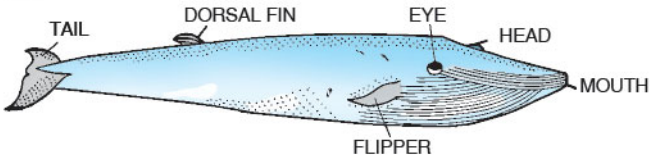


Fig. 31. *Balaenoptera*—Whale.

7. Carnivores (L. *carnos* = flesh; *vorare* = to eat)

(*i*) These are **cursorial** and **digitigrade.**

(*ii*) **Canines** are very well developed while incisors are reduced.

(*iii*) These are **carnivorous** so even premolars become sharp and pointed (called **carnisial teeth**) for tearing the prey.

Examples : *Panthera tigris* (Tiger with vertical strips); **Wolf** *(Canis lupus);* **Polar bear** *(Ursus);* **Lion** *(Panthera leo);* **Dog** (*Canis familiaris*); **House cat** *(Felis domesticus); Phoca* **(Seal);** etc.

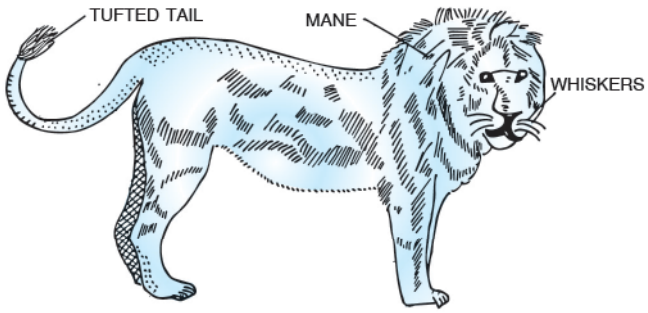


Fig. 32. *Panthera leo*—Lion

8. Pholidotes (Gr. *pholis* = a horny scale)

(*i*) Body is covered by **overlapping scales** (modified hair).

(*ii*) Teeth are absent.

(*iii*) Tongue is long slender and **protrusible.**

(*iv*) **Insectivores.**

(*v*) Each limb has **five clawed digits** *e.g., Manis* **(Scaly-ant eater** or **pangolin).**

9. Proboscids (Gr. *pro* = in front; *boskein* = to eat)

(*i*) Upper lip and snout are elongated to form **proboscis** or **trunk.**

(*ii*) Upper incisors are elongated to form **tusks.** Canines are absent.

(*iii*) Air cavities in the bones of head.

(*iv*) Scanty hair growth.

(*v*) Eyes are small sized while ears are large sized.

(*vi*) Testes are abdominal.

(*vii*) Teats are only one pair and thoracic.

(*viii*) Digits are embedded in common integument and have pads on the lower surface. These are **digitigrade.**

Example : *Elephas indicus*—**Indian elephant.**

10. Artiodactyles (Gr.= *artios* = even; *dactylos* = digit)

(*i*) These are **cursorial and even-hoofed mammals.**

(*ii*) These show **unguligrade** locomotion.

(*iii*) These have **compound stomach: 4** chambered (rumen, reticulum, omasum and abomasum).

(*iv*) **Symbiotic digestion of cellulose** in their rumen part of stomach. These are **herbivores.**

(*v*) These **regurgitate** (back flow) the food bolus called **cud** from stomach to buccal cavity, so called **cud-chewing mammals.**

(*vi*) Many members have **horns** or **antlers.**

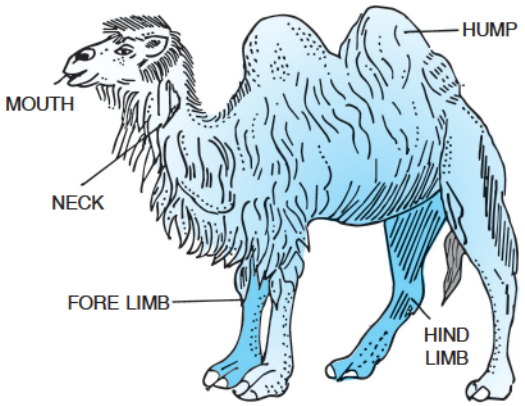


Fig. 33. *Camelus*—Camel

Example : *Camelus bactrianus* **(Turkish camel).**

Other important members of Artiodactyla are : cow, buffalo, sheep, goat, deers, hippopotamus.

11. Perissodactyles (Gr. *perissos* = odd; *dactylos* = digit)

(*i*) These are **cursorial** and **odd-hoofed mammals.**

(*ii*) These are **unguligrade.**

(*iii*) Stomach is simple but **caecum is large sized.** These are **herbivores.**

(*iv*) These **do not** show **rumination.**

(*v*) Horns are absent.

Example : *Equus cabalus* **(Horse).**

The artiodactyles and perissodactyles are collectively grouped under **Ungulates** (**hoofed herbivores**). These are cursorial and herbivorous.

Other members of Perissodactyla are : *Rhinoceros* : (with 3 functional hoofed digits. Skin is very thick and folded. Horn is formed of only horny skin with no bone and is replaced). Indian rhinoceros has one horn while African rhinoceros has two horns. Horn has medicinal value. Rhinoceros is very commonly found in **Kaziranga National Park** and **Manas sanctuary (Assam).** *Equus vulgaris* **(Ass)**: differs from the horse in having erect mane, large sized pinnae, only lower part of tail being hairy, small body and narrow hoofs. *E. zebra* (**Zebra** with striped belly), and **mule** (an intergeneric hybrid of the male ass and mare) while **hinny** is an intergeneric hybrid of she-ass and stallion. Both are sterile.

MAMMALS (ESPECIALLY PRIMATES) AS MOST SUCCESSFUL AND ADAPTED ANIMALS

1. Presence of an insulating and protective **hairy exoskeleton.**

2. These are **homeothermal** or **warm-blooded** or **endothermic** animals so have high rate of metabolism.

3. Presence of well–developed brain with **large sized cerebrum, four optic lobes** and a nervous band called **corpus callosum.** Grey matter is more developed so have more intelligency.

4. These are **viviparous** animals and show placentation and intrauterine development which increases the chances of survival of young ones.

5. These show high degree of **parental care.** Mothers feed upon the youngs on the milk of their **mammary glands.**

6. These have **more developed hearing efficiency** due to presence of pinna, three ear-ossicles and coiled cochlea in the ear.

7. These have good **power of learning** due to presence of better developed brain.

8. Ability of **speech** through language.

9. Grasping power due to thumb opposability to fingers.

LEARNING PLUS

- In snakes and some lizards, the limbs are secondarily absent.
- In reptiles and birds, cloaca is three chambered for conservation of water.
- Aquatic reptiles *e.g.*, Turtles are **ureotelic** in excretion.
- When disturbed, tortoise can withdraw all the body parts in a tortoise shell.
- Tortoise is the symbol of long life span (200 years).
- **Crocodile** is the largest amphibious reptile. It has certain mammalian characters.
- *Eudynamis* **(Koel)** : It is commonly called **Indian Nightingale.**
- *Tyto* **(Owl)** is **nocturnal bird of prey.** It has **keenest eye sight** at night and has binocular vision. It is important in **biological control** of rats in the fields.
- In **Hedgehog**, hair of dorsal side of trunk are modified into spines for defence.
- Insectivores are simplest true placental mammals.
- **Kitti's hog-nosed bat** (*Craseonycteris*) is the smallest mammal, while the **blue whale** (*Balaenoptera*) is not only the largest mammal but also the largest animal.

LEARNING PLUS

- **Small bats** have claw only on first digit of fore limb and have tail. Bats hang downward from tree branches as these cannot stand erect.
- **Lion** is found in Gir forests of Gujarat. Male is **polygamous** and has a **mane.** Digits have retractile claws.
- **Monkeys** are quadrupedal, tailed, with equal sized limbs and ischial callosities, while **apes** are bipedal, tailess, with longer fore limbs but without ischial callosities.
- **African elephant** is larger in size, has depressed back, large sized pinnae and large sized tusks only in males.
- Elephant is **largest terrestrial animal.** Indian elephant has tusks in both the sexes.
- **Turkish camel** is a two-humped camel found in Gobi desert of Central Asia, while **Arabian camel** is one-humped camel found in North Africa to India.
- **Camels** are characterized by **hump** (store house of fat), **water cells** in stomach (to store metabolic water), **pads** beneath two digits, dense hair growth near eyes and nostrils, and nucleated RBCs. It is called **ship of desert.**
- **Baleen** is a set of hanging plates in the buccal cavity of blue whale.
- River dolphin is the National Aquatic Animal of India.

PRACTICE PROBLEMS – AVES AND MAMMALIA

126. Define ornithology.
127. List three flight adaptations in the body.
128. Why are the birds called feathered-bipeds?
129. What is peculiar about the lungs of the birds?
130. What do you mean by cledoic nature of eggs of reptiles and birds?
131. Why are birds and mammals called homeothermal animals?
132. What is peculiar about ostrich?
133. Why is kite called diurnal bird of prey?
134. Discuss sexual dimorphism in peacock.
135. What is peculiar about the breeding habit of koel?
136. List two peculiarities of owl.
137. What is pigeon's milk? Give its function.
138. Name two types of glands present in the skin of mammals.
139. List three peculiar characters of mammals.
140. Why are reptiles, birds and mammals called amniotes?
141. List two peculiar characters of prototherians.
142. What is evolutionary significance of duck-billed platypus?
143. What are metatherians? Give one example.
144. Give two flight adaptations in the bats.
145. What are cetaceans? List two peculiarities of them. Give one example.
146. Rabbit is called a coprophagous animal. Why?
147. Give two peculiar characters of carnivores. Give one example.
148. What are primates? List two peculiar characters of them. Give two examples.
149. List two peculiar characters of proboscids?
150. Give three desert adaptations in the camel.

ANSWERS TO PRACTICE PROBLEMS

126. Study of birds.
127. **Streamlined body, pneumatic bones** and **wings** as flight organs.
128. Body is externally covered by **feathery exoskeleton** and use two hind limbs on ground.
129. Lungs are associated with **air sacs** which help in **double respiration** and acts as **internal cooling agents.**
130. Cledoic egg is **polylecithal, shelled** and **self-sufficient.**
131. Both have **constant body temperature** which does not change with change in environmental temperature.
132. Ostrich is **largest bird.** It is **flightless** bird and lays **largest sized eggs.**
133. Kite is active during **daytime** and is a **predatory bird.**

Table 24. Basic characteristics of different phyla of kingdom Animalia.

Phylum → Character ↓	Porifera	Coelenterata	Ctenophora	Platy-helminthes	Aschel-minthes	Annelida	Arthropoda	Mollusca	Echino-dermata	Hemi-chordata	Chordata
Distinctive Feature	Pore-bearing animals	Presence of cnidoblasts	Locomotion by comb plates	Leaf or ribbon-like flat body	Thread-like body	Segmented body due to-annuli	Jointed appendages	Soft-bodied animals	Spiny-skinned animals	Presence of stomochord	Presence of of notochord
Level of organisation	Cellular	Tissue	Tissue	Organ-system	Organ-system	Organ-system	Organ-system	Organ-system	Organ-system	Organ-system	Organ-system
Symmetry	Mostly Radial	Radial	Biradial	Bilateral	Bilateral	Bilateral	Bilateral	Mostly Bilateral	Pentamerous Radial	Bilateral	Bilateral
Germ layers	Diploblastic	Diploblastic	Diploblastic	Triplo-blastic	Triploblastic	Triploblastic	Triploblastic	Triploblastic	Triploblastic	Triploblastic	Triploblastic
Body cavity	Acoelomates	Acoelomates	Acoelomates	Acoelomates	Pseudo-coelomates	Eucoelo-mates	Haemo-coelomates	Haemo-coelomates	Eucoelo-mates	Eucoelo-mates	Eucoelo-mates
Locomotory organs	Absent	Absent or Floating	Comb plates	Absent	Absent	Setae or parapodia or suckers	Jointed Legs	Foot	Tube feet	Absent	Fins or limbs
Alimentary canal	Absent	Incomplete	Complete	Incomplete	Complete and straight	Complete and straight	Complete and coiled	Complete and coiled	Complete and straight	Complete	Complete and coiled
Respiratory structure	Body surface	Body surface	Body surface	Absent or Body surface	Absent or Body surface	Skin or Gills or Parapodia	Gills or Book gills or Bood lungs or Tracheae	Gill or Pulmonary sac	Dermal branchiae	Gill slits	Gills or lungs
Circulatory system	Water-vascular system	Coelenteron or Gastrovas-cular cavity	Absent	Parenchymal circulation	Pseudo-coelomic fluid circulation	Closed type	Open type	Open type	Open Haemal system	Closed type	Closed type
Excretory Structures	Body surface	Body surface	Body surface	Flame cells	Intracellular Renett cell	Nephridia	Antennary gland or Malpighian tubules or coxal glands	Organs of Bojanus	Dermal branchiae	Proboscis gland	Mostly kidneys
Other peculiar feature	Choanocytes and Canal system	Cnidoblasts mostly polymorphic	Colloblasts cydipid larva	Ladder-like nervous system	Fixed no. of cells (Eutyly)	Metameric segmentation	Mouth parts & sclerotized skeleton	Shell, pallium osphradium	Free-swimming bilateral symmetrical larva	Tornaria larva	Dorsal and hollow nervous system. Gill slits for respiration.

134. Male peacock has **crest** on head, brightly coloured plumage, long and **ocellated tail feathers**, and a **bony spur** on leg for fighting.
135. Female koel lays its **eggs in the crow's nest.**
136. Nocturnal in activity, predatory in feeding, binocular vision, noiseless flight, etc.
137. A **nutritive secretion** of **crop glands** of some female birds. It is regurgitated and fed to young birds.
138. **Sweat glands** and **oil glands.**
139. (i) Presence of **hairy** exoskeleton (ii) Milk-producing **mammary glands** (iii) mostly **viviparous.**
140. As the embryonic stage is surrounded by **embryonic membranes** like amnion chorion, etc.
141. **(i) Egg-laying mammals** (ii) No nipples and pinna.
142. It acts as a **connecting link** between reptiles and mammals.
143. Marsupials are pouched mammals having a **marsupium** in female e.g. Kangaroo.
144. (i) Flight organs are **patagia** supported by fore limbs. (ii) **Pneumatic bones.**
145. Cetaceans are **aquatic mammals** e.g. whale. Body is streamlined, forelimbs as paddles, loss of hind limbs and body hair, a thick fatty blubber beneath the skin, etc.
146. Cellulose of vegetable food of rabbit is symbiotically digested by bacteria in caecum and vermiform appendix and is egested with faeces. Rabbit eats its own faeces (called **coprophagy** or **refection**) to use simplified cellulose.
147. (i) cursovial (ii) **canines large sized** (iii) Reduced incisors (iv) **Retractile claws** e.g. lion, tiger, cat, etc.
148. Primates are **most intelligent** mammals having **binocular vision, grasping power** in hands, **nails** on the digits and only one pair of **thoracic nipples,** etc. e.g. monkeys, apes, human beings etc.
149. Proboscids include elephants which have **proboscis** (snout + upper lip), tusks, large sized pinnae, less hair growth, etc.
150. (i) **Hump** with stored food as fats. (ii) **Water cells** in stomach to store metabolic water. (iii) **Pads** beneath two digits.

ADDITIONAL USEFUL INFORMATIONS ABOUT MAMMALIA FOR COMPETITIVE EXAMINATIONS

- *Mammals evolved form cyanodont reptiles during Jurassic period of Palaeozoic era about **210 million years ago.***
- ***Primates** evolved from tree shrews about **65 million years ago** (Palaeocene epoch).*
- *Hair in the mammals serve variety of functions: insulation against the cold, protection for delicate skin, camouflage against predators (e.g. in zebras and giraffes), give sensory feedback (e.g. whiskers of cats, rabbits, etc.), etc.*
- *A hairy coat is called **pelage** and is of two types: **undercoat hair** (small sized and insulatory) and **guard hair** (long sized and protective).*
- *Mammals vary in size and range from the tiny 1 to 2 inch **bumblebee bat** to about 108-feet **blue wale.***
- *Jaw suspension is **craniostylic** (dentary bone of lower jaw suspended from squamosal bone of upper jaw).*
- ***Choloepus (2-toed sloth)** and **Trichechus (manatee)** have 6 vertebrae, while **Bradypus (3-toed sloth)** has 9 vertebrae.*
- ***True salivary glands** (with Ptyalin enzyme) are present in some mammals only e.g. human beings, rabbit, pig, etc.*
- ***Thyroid cartilage** in the larynx is present only in the mammals.*
- *Elephants, whales and seals have **abdominal testes.***
- *Young may be **nidifugous** or **precocial** (e.g. cattle) or **nidiculous** or **altricial** (e.g. cats, rats, etc.)*
- *Mammals are **highly intelligent** animals due to their well developed cerebrum and learnt behaviour.*
- *Three groups of mammals :*
  *(a) **Prototherians** : egg-laying mammals. (b) **Metatherians** : Pouched mammals. (c) **Eutherians** : True placental mammals.*
- ***Echidna** or **Tachyglossus (Spiny ant eater)** : another prototherian of Australia, New Guinea, etc. It is insectivorous and **ant eater** (so is toothless). Hair on the back are modified into **spines** for defence.*
- ***Didelphis virginiana (North American opossum)** : An arboreal metatherian of America and has a prehensile tail.*
- ***Vampires** : Blood-sucking bats **(Sanguivorous).***
- ***Male Dayak fruit bat** has functional mammary glands for breast feeding.*
- *Mammary glands are modified and enlarged sweat glands.*
- ***National animal of India** : Tiger **(Panthera tigris).*** ● ***Hare lip** : Cut upper lip in rodents and rabbits.*
- ***Largest mammal (animal)** — Blue whale.*
- ***Largest land mammal** — African Elephant (Loxodonta africana) –3.45 m.*
- ***Second largest animal in India** — One horned rhinoceros.* ● ***Smallest mammal** — Water shrew.*
- ***Fastest mammal** — Cheetah (Speed = 120 km/hour).*
- ***Armadillo** —It also shows **polyembryony** (one zygote producing four to eight youngones).*
- ***Frugivorous bats** are large sized, fruit eating and tailless e.g. **Pteropus** (Flying fox), while **carnivorous bats** are small sized, eat upon the insects and tailed e.g. **Scotophilus.***
- ***Apes differ from man** in the characters like : Mainly arboreal, semi-erect posture, prominent eye brow ridges, arms longer than legs, only one curve in vertebral column, both pollex and hallux are opposable.*

- *Vibrissae — Long, stiff and tactile hair on lips found in rodents, carnivores, etc.*
- *Platanista gangetica (Dolphin) is second most intelligent mammal and has very high learning powers.*
- *Whaling : Hunting of whales for its blubber.*
- *Other Artiodactyles are :*
  - *Giraffa (giraffe) : It is tallest (about 16 feet in height) living animal found in desert-like areas in the south of Sahara.*
  - *Hippopotamus (Hippopotamus - Horse of river - Fig. 23) : It is an amphibious and bulkiest mammal of of land mammal.*
  - *Cervus axis (spotted deer or chital) : It is a cursorial, gregarious, diurnal and herbivorous cud chewing mammal. Body is reddish-brown with white spots. Male has branched horns, called antlers, formed of only bone with no skin cover and are replaced every year. It shows alturism.*
- *Other Perissodactyles are :*
  - *Tapirus (Tapir) is most primitive perissodactyle.*
  - *Equus vulgaris (Ass) : differs from the horse in having erect mane, large sized pinnae, only lower part of tail being hairy.*
  - *E. zebra (Zebra with striped belly).*

CHAPTER SUMMARY

- Animals are multicellular like plants but lack plastids, cell wall and central vacuole but have centrosome, and are heterotrophic in nutrition, generally have indirect development and locomotory structure and receptors.
- Regarding habitat, animals are either aquatic (marine or fresh-water) or terrestrial. Later may be fossorial, arboreal, scansorial, cursorial, etc.
- Animals have either cellular or tissue or organ system organization.
- Body plan is either cell aggregate or blind sac or tube-within-tube.
- Animals have either spherical or radial or biradial or lateral symmetrical body.
- Repetition of internal body parts is called **metamerism.** Vertebrates have internal metamerism, while arthropods have external metamerism and annelids have **metameric segmentation**.
- Animals are either **acoelomates** or **pseudocoelomates** or **haemocoelomates** or **eucoelomates.**
- On the basis of germ layers, animals are either **diploblastic** or **triploblastic**.
- Organs of respiration are different in animals. Respiration may be through body surface or branchial or cutaneous or tracheal or pulmonary or with the help of book gills or book lungs.
- Circulatory system is either **open type** (e.g. arthropods & molluscs) or **closed type** (e.g. Most of annelids, cephalopods and vertebrates). Blood is colourless in insects, blue in molluscs (due to haemocyanin) and red-coloured in the vertebrates (due to haemoglobin).
- Regarding excretion, animals are **ammonotelic** or **ureotelic** or **uricotelic.** Excretion occurs by either body surface or protonephridia (flame cells) or rennet cell or nephridia or green glands or coxal glands or malpighian tubules or kidneys.
- Nervous system is diffused type in coelenterates, ladder type in flat and roundworms and centralized nervous system in annelids, arthropods and vertebrates.
- Some animals show asexual reproduction but most of animals show sexual reproduction. Sexes are either unisexual or bisexual. Fertilization is either internal or external. On the basis of breeding behaviour, animals are either **oviparous** or **viviparous**. Development is direct or indirect (with some larval stage).
- Regarding body temperature, animals are either **poikilothermal** (cold blooded) or **homeothermal** (warm-blooded).
- On the basis of notochord, the animals are of 2 types: **Non-chordates** and **chordates**.
- Non-chordates form about 95% of the animals and are classified into a number of phyla: Porifera, Coelenterata, Ctenophora, Platyhelminthes, Aschelminthes, Annelida, Arthropoda, Mollusca, Echinodermata and Hemichordate.
- **Phylum Porifera** includes **sponges** (pore bearing animals) and are characterized by 2 types of pores, cellular organisation, diploblastic, ammonotellic, mostly marine, canal system, calcareous or siliceous or spongin endoskeleton, amphiblastula in development, etc.
- **Phylum Coelenterata or Cnidaria** is characterized by presence of coelenteron , tissue-organization, diploblastic, cnidoblasts (stinging cells) in epidermis, ammonotelic excretion, mostly polymorphic (with many types of zooids) metagenesis, etc.
- **Phylum Ctenophora** includes marine as well as fresh-water animals with tissue organisation, biradial symmetry, diploblastic, complete gut, ammonotelism, and presence of cydipid larva in development. These have comb jellies for locomotion, colloblasts on tentacles and statocyst for balancing.
- **Phylum Platyhelminthes** includes flat worms (planarians, flukes and tapeworms) which are characterized by organ-system organization, blind sac plan, bilateral symmetry, triploblastic nature, mostly parasitic, ladder-like nervous system, flame cells for excretion.
- **Phylum Aschelminthes** includes **roundworms** (eg. *Ascaris*, filarial worm, hookworm, etc.) These are characterized by long cylindrical body without appendages, pseudocoelomates, complete gut, excretion by Rennet cell, syncitial epidermis, ladder-nervous system and always with sexual dimorphism.

- **Phylum Annelida** includes **segmented worms** (e.g. earthworms, leeches, *Nereis* etc. These are characterized by : metameric segmentation, true coelom divided by septa, straight and complete gut, nephridia as excretory organs, closed circulatory system, some are bisexual but some are unisexual. **Trochophore larva** in development of some forms.
- **Phylum Arthropoda** includes about 80% of animal and includes insects, prawns, crabs, centipedes, millipedes, scorpions, spiders, etc. These are characterized by : hoemocoel, open circulatory system, sclerotized exoskeleton, mouth parts, jointed appendages, coiled and complete gut, respiration by gills or tracheae or book lungs or book gills, excretion by antennary glands or Malpighian tubules or coxal glands, mostly having compound eyes, development is either direct or indirect (with some larval stage e.g. **caterpillar larva** in life cycle of butterflies and moths).
- **Phylum Mollusca** includes snails, slugs, oysters, *Chiton*, *Octopus*, *Sepia*, *Loligo*, etc. These animals are soft bodied, haemocoelomates, with open circulatory system, presence of pallium and shell, radula in buccal mass, respiration with gill or pulmonary sac, blood is blue due to haemocyanin, development generally includes **glochodium larva**.
- **Phylum Echinodermata** includes **spiny-skinned** animals like starfishes, sea urchins, sea cucumbers, feather star, etc. These are characterized by : pentamerous radial system, water-vascular system with tube feet, marine, unisexual, always indirect development, etc.
- **Phylum Hemichordata** includes tongue-worm. Their body is worm-like, divided in 3 parts, respiration by gillslits, excretion by proboscis gland and **tornaria larva** in their development.
- **Phylum Chordata** is characterized by presence of notochord; dorsal hollow CNS, gill slits and tail. It is divided into 3 sub-phyla: Urochordata, Cephalochordata and Vertebrata. Urochordates and cepchalochordates are collectively called **Protochordates** or **Acraniates** (no brain box).
- **Urochordata** includes *Herdmania*, *Salpa*, *Doliolum*, etc. These animals have notochord only in their tail region of larva which is lost during retrogressive metamorphosis. Body is covered by test, pharynx is branchial basket, excretory organ is neural gland, etc.
- **Cephalochordates** (e.g. *Amphioxus*) have all chordate characters throughout life .
- **Subphylum Vertebrata** (also called **Craniata**) are characterized by: replacement of notochord by vertebral column, Brain of CNS enclosed in cranium; closed circulatory system; kidneys for excretion; cartilaginous or bony endoskeleton; internal metamerism; one pair of gonads; etc. Vertebrata is divided into jawless **Agnathostomata** and jawed **Gnathostomata**.
- Agnathostomata includes **cyclostomates** (e.g. sea lamprey and Hagfish) which are characterized by circular mouth, generally ectoparasites of fishes, only median fins, monorhinus, 2- chambered heart, 6 to 15 pairs of gill slits; and **ammocoetes larva** in development .
- Gnathostomata is divided into 2 superclasses : **Pisces** (fishes) and **Tetrapoda**. Super class Pisces includes two classes : **Chondrichthyes** and **Osteichthyes**.
- **Class Chondrichthyes** includes **cartilage fishes** like sharks, stingray, electric ray, saw fishes, great white shark, etc. These are characterized by: marine habitat, locomotion by fins, heterocercal tail fin, 2 dorsal fins, gills for respiration, ventral mouth, cloacal aperature, 2-chambered heart, 10 pairs of cranial nerves, lateral line system, claspers in males, ureotelism and cartilaginous endoskeleton.
- **Class Osteichthyes** includes **bony fishes** which differ from cartilage fishes in characters like: freshwater or marine in habitat, endoskeleton mainly of bones, presence of anus, single dorsal fin, homocercal or diphycercal tail fin ammonotelism, etc. But in many characters these resemble the cartilage fishes.
- **Super class Tetrapoda** is divided into four classes : **Amphibia**, **Reptilia**, **Aves** and **Mammalia** on the basis of nature of exoskeleton.
- **Class Amphibia** includes caecilians, frogs, salamanders, etc. and is characterized by : amphibious habitat, glandular skin, absence of exo-skeleton, cutaneous respiration, wide mouth, cloacal aperture, 3-chambered heart, single ear ossicle in middle ear, ureotelism, generally indirect development , etc.
- **Class Reptilia** includes tortoises, turtles, lizards, snakes, crocodiles, etc. These are characterized by generally creeping locomotion, an exoskeleton of epidermal scales or scutes, carnivorous, wide mouth, cloacal aperture, only pulmonary, respiration, mostly 3-chambered heart, uricotelism, oviparous laying shelled and polylecithal eggs.
- **Class Aves** includes **birds** which are characterized by: streamlined body: an exoskeleton of feathers, bipedal locomotion, forelimbs modified into wings, toes adapted for perching, mouth bounded by beak, presence of food storing crop and food masticating gizzard, lungs with air sacs for double respiration, 4- chambered heart, 12-pairs of cranial nerves, trilobulated kidneys, uricotelism, always oviparous, right ovary and oviduct vestigeal, homeothermal, etc.
- **Class Mammalia** includes **mammals** like platypus, rodents, bats, lion, tigers, ruminants, humans, apes, monkeys, etc. These are characterized by mammary glands, hairy exoskeleton, skin with sweat and oil glands, diaphragm, heterodont and thecodont teeth, anus, respiration by lungs, 4-chambered heart, bean-shaped kidneys, ureotelism, 3 ear-ossicles in middle ear, pinna in external ear, mostly viviparous and homeothermal. Mammals are most successful and adapted animals due to hairy exoskeleton, homeothermy, large sized cerebrum, viviparity, power of speech and learning, grasping power, etc.

KEY TERMS

Ammonotelism	:	Excretion in which main nitrogenous waste is NH_3.
Aestivation : Summer sleep	:	Animal hides to save itself from prolong high temperature.
Autotomy	:	Power of losing body parts in self-defence *e.g.*, **Prawn.**
Benthos	:	Organisms living on the bottom of water bodies *e.g.*, echinoderms.
Choanocyte	:	Flagellated collar cells of sponges.
Coelenteron	:	Central cavity of coelenterates.
Deuterostomous	:	Blastopore of gastrula forms anus earlier than mouth *e.g.*, **chordates.**
Diploblastic	:	Having two germ layers of cells.
Haemocoel	:	A body cavity filled with blood *e.g.*, arthropods and molluscs.
Hermaphrodite : Bisexual	:	When both the sex-organs are present in same organism *e.g.*, earthworm, leech, *Taenia* etc.
Homeothermal	:	Constant body temperature.
Metameric segmentation	:	External division of body corresponds with internal division of coelom *e.g.*, **Annelids.**
Metamorphosis	:	Larval stage changes into adult stage *e.g.*, **Tadpole larval stage.**
Nocturnal	:	Active during night *e.g.*, owls, cockroach etc.
Oviparous	:	When female lays only eggs.
Pheromone	:	Secretions of glands which are released in air. These generally act as sex attractant.
Poikilothermal, Cold-blooded	:	Body temperature is not constant and changes with the environmental temperature.
Polygamy	:	When one male lives in the company of many females *e.g.*, *Struthio.*
Polymorphism	:	The occurrence of at least two, usually several, radically different body forms within colonial or social organisms.
Protandrous	:	In bisexual organisms testes mature earlier than ovaries *e.g.*, **earthworm.**
Protogynous	:	In bisexual organism, ovaries mature earlier than the testes *e.g.*, *Scypha.*
Protostomous	:	Blastopore of gastrula forms mouth earlier than anus *e.g.*, **annelids.**
Pseudocoel	:	A body cavity not lined by peritoneal layers *e.g.*, in **nematodes.**
Schizocoel	:	Coelom formed by division of mesoderm *e.g.*, **in annelids.**
Sanguivorous	:	Organism feeding upon blood of other animal *e.g.*, **leech.**
Sexual dimorphism	:	When two sexes of species are externally different.
Thecodont	:	Teeth are present in sockets of jaw bones *e.g.*, mammals.
Triploblastic	:	Having three germ layers of cells in gastrula larva.
Unisexual	:	When sexes are saparate *e.g.*, human beings.
Unguligrade	:	Running on the tips of digits *e.g.*, Horse, Rhinoceros, Ass, Zebra, Giraffe etc.
Ureotelism	:	Excretion type in which main nitrogenous waste is urea *e.g.* mammals.
Uricotelism	:	Excretion-type in which main nitrogenous waste is uric acid *e.g.*, most of reptiles and all birds.
Viviparous	:	Giving birth to living

NCERT FILE *Solved*

NCERT Exercise Questions

1. What are the difficulties that you would face in classification of animals, if common fundamental features are not taken into account?

Ans. During classification of animals, the fundamental features like level of organisation, symmetry, body plan, germ layers, body cavity, segmentation, notochord, etc. must be taken into account otherwise adaptive radiations, convergent evolution, vestigial organs, etc. may pose difficulties in the process of classification.

2. If you are given a specimen, what are the steps that you would follow to classify it?

Ans. I will observe its fundamental features like level of organisation, symmetry, body plan, germ layers, body symmetry, coelom, segmentation and patterns of digestive, circulatory and reproductive systems.

3. How useful is the study of the nature of body cavity and coelom in the classification of animals?

Ans. Study of nature of body cavity (coelom) indicates whether the animal is acoelomate (without coelom) or pseudocoelomate (with false coelom) or haemocoelomate (coelom with blood) or schizocoelomate (coelom formed by splitting of mesoderm) or enterocoelomate (coelom formed from archenteron). This will help in assigning the exact taxonomic position of animal.

4. Distinguish between intracellular and extracellular digestion.

Ans. **Intracellular digestion**, also called **vacuolar digestion**, occurs in a food vacuole inside the cell and is found in lower animal groups like protozoans and sponges. **Extracellular digestion**, also called **intercellular digestion**, occurs in the lumen of alimentary canal of higher animals like annelids, crustaceans, insects, cephalopods and vertebrates.

5. What is difference between direct and indirect development?

Ans. In direct development, youngone resembles the adult in morphology and physiology *e.g.* human beings, while in indirect development, youngone differs from the adult in morphology and physiology *e.g.* tadpole larva of frog.

6. What are the peculiar features, that you find in parasitic platyhelminthes?

Ans. **(i)** Absence of epidermis and presence of resistant cuticle.
(ii) Sense organs are reduced or absent.
(iii) Presence of adhesive organs like suckers or hooks or both.
(iv) Absence of organs of locomotion.
(v) Alimentary canal absent in tape worms.

7. What are the reasons that you think of for the arthropods to constitute the largest group of the animal kingdom?

Ans. Presence of sclerotised exoskeleton of chitinous plates which helps in :
(i) Protection from the predators and prevents the loss of water.
(ii) Modified to form wings for flying in the insects.
(iii) Provides surface for attachment of voluntary muscles.
(iv) Forms mouth parts for feeding.

8. Water vascular system is the characteristic of which group of the following?
(a) Porifera (b) Ctenophora (c) Echinodermata (d) Chordata

Ans. (b) Echinodermata (Porifera is with canal system).

9. "All vertebrates are chordates but all chordates are not vertebrates." Justify the statement.

Ans. Because all the vertebrates have notochord and gill slits at least in their embryos but there are certain chordates like *Herdmania* and *Amphioxus* which do not have vertebral column in any stage of their life cycle.

10. How important is the presence of air bladder in Pisces?

Ans. Air bladder in bony fishes acts as a hydrostatic organ so helps in balancing the body in water.

11. What are the modifications that are observed in birds that help them fly?

Ans. See page no. 46-47 of chapter 4.

12. Could the number of eggs or youngones produced by an oviparous and viviparous mother be equal? Why?

Ans. An oviparous animal always produces more number of eggs than the young ones produced by a viviparous animal because their eggs are exposed more to external unfavourable conditions and predators so have less chances of survival than the foetus developing inside the mother's body. Large number of eggs compensates the inevitable loss and ensures the continuation of race.

13. Segmentation in the body is first observed in which of the following?
(a) Platyhelminthes (b) Aschelminthes (c) Annelida (d) Arthropoda

Ans. (c) Annelida

14. Match the following :

Column A	Column B
(a) Operculum	(i) Ctenophora
(b) Parapodia	(ii) Mollusca
(c) Scales	(iii) Porifera
(d) Comb plates	(iv) Reptilia
(e) Radula	(v) Annelida
(f) Hair	(vi) Cyclostomata & Chondrichthyes
(g) Choanocytes	(vii) Mammalia
(h) Gill slits	(viii) Osteichthyes

Ans. (a) (viii); (b) (v); (c) (iv); (d) (i); (e) (ii); (f) (vii); (g) (iii); (h) (vi);

15. Prepare a list of some animals that are found parasitic on / in human beings.

Ans. **(i)** *Taenia solium* (Pork tape worm)
(ii) *Schistosoma* (Blood fluke)
(iii) *Ascaris* (Round worm)
(iv) *Wuchereria* (Filarial worm)
(v) *Ancylostoma* (Hookworm)
(vi) *Pediculus* (Head louse)

NCERT Exemplar Problems

A. MULTIPLE CHOICE QUESTIONS

1. In some animal groups, the body is found divided into compartments with at least some organs/organ repeated. This characteristic feature is named:
(a) Segmentation (b) Metamerism
(c) Metagenesis (d) Metamorphosis

2. Given below are types of cells present in some animals. Each one is specialized to perform a single specific function except:
   (a) Choanocytes (b) Interstitial cells
   (c) Gastrodermal cells (d) Nematocysts
3. Which one of the following sets of animals share a four chambered heart?
   (a) Amphibian, Reptiles, Birds
   (b) Crocodiles, Birds, Mammals
   (c) Crocodiles, Lizards, Turtles
   (d) Lizards, Mammals, Birds
4. Which of the following pairs of animals has non-glandular skin:
   (a) Snake and Frog
   (b) Chameleon and Turtle
   (c) Frog and Pigeon
   (d) Crocodile and Tiger
5. Birds and mammals share one of the following characteristics as a common feature:
   (a) Pigmented skin
   (b) Alimentary canal with some modification
   (c) Viviparity
   (d) Warm blooded nature
6. Which one of the following sets of animals belong to a single taxonomic group?
   (a) Cuttlefish, Jellyfish, Silverfish, Dogfish, Starfish
   (b) Bat, Pigeon, Butterfly
   (c) Monkey, Chimpanzee, Man
   (d) Silkworm, Tapeworm, Earthworm
7. Which one of the following statements is incorrect?
   (a) Mesoglea is present in between ectoderm and endoderm in *Obelia*
   (b) Radial symmetry is found in *Asterias*
   (c) *Fasciola* is a pseudocoelomate animal
   (d) *Taenia* is a triploblastic animal
8. Which one of the following statements is incorrect?
   (a) In cockroaches and prawns excretion of waste material occurs through Malpighian tubules.
   (b) In ctenophores, locomotion is mediated by comb plates.
   (c) In *Fasciola*, flame cells take part in excretion
   (d) Earthworms are hermaphrodites and yet cross fertilization take place among them.
9. Which one of the following is oviparous?
   (a) Platypus (b) Flying fox (Bat)
   (c) Elephant (d) Whale
10. Which one of the following is not a poisonous snake?
   (a) Cobra (b) Viper
   (c) Python (d) Krait
11. Match the following list of animals with their level of organisation:

Division of Labour	Animal
(A) Organ level	(i) *Pheritima*
(B) Cellular aggregate level	(ii) *Fasciola*
(C) Tissue level	(iii) *Spongilla*
(D) Organ system level	(iv) *Obelia*

   Choose the correct match showing division of labour with animal example.
   (a) (i)-(B) (ii)-(C) (iii)-(D) and (iv)-(A)
   (b) (i)-(B) (ii)-(D) (iii)-(C) and (iv)-(A)
   (c) (i)-(D) (ii)-(A) (iii)-(B) and (iv)-(C)
   (d) (i)-(A) (ii)-(D) (iii)-(C) and (iv)-(B)
12. Body cavity is the cavity present between body wall and gut wall. In some animals the body cavity is not lined by mesoderm. Such animals are called:
   (a) Acoelomate (b) Pseudocoelomate
   (c) Coelomate (d) Haemocoelomate
13. Match the column A with column B and choose the correct option:

Column A	Column B
(A) Porifera	(i) Canal system
(B) Aschelminthes	(ii) Water-vascular system
(C) Annelida	(iii) Muscular pharynx
	(iv) Jointed appendages
(D) Arthropoda	(v) Metameres
(E) Echinodermata	(vi) Comb plates

   (a) (A)-(ii) (B)-(iii) (C)-(v) (D)-(iv) (E)-(i)
   (b) (A)-(ii) (B)-(v) (C)-(iii) (D)-(iv) (E)-(i)
   (c) (A)-(i) (B)-(iii) (C)-(v) (D)-(iv) (E)-(ii)
   (d) (A)-(i) (B)-(v) (C)-(iii) (D)-(iv) (E)-(ii)

ANSWERS

1. (b);	2. (b);	3. (b);	4. (b);	5. (d);	6. (c);	7. (c);
8. (a);	9. (a);	10. (c);	11. (c);	12. (b);	13. (c).	

HINTS OF SOME DIFFICULT MULTIPLE CHOICE QUESTIONS

2. (b) : Interstitial cells are totipotent cells found in the coelenterates. These are undifferentiated and help in repair and regeneration.

7. (c) : *Fasciola* (Liver fluke) is a flat worm found in phylum Platyhelminthes which includes acoelomate animals due to presence of parenchyma.

12. (b) : A body cavity lined by mesoderm is called true coelom, while the body cavity not lined by mesoderm is called pseudocoel. It is found in round worms of Aschelminthes.

B. VERY SHORT ANSWER TYPE QUESTIONS

1. Identify the phylum in which adults exhibit radial symmetry and larvae exhibit bilateral symmetry.

Ans. Phylum Echinodermata e.g. *Asterias* (starfish).

2. What is importance of pneumatic bones and air sacs in Aves?

Ans. **(i) Pneumatic bones** are with air cavities and make the body light for flight.

(ii) Air sacs in Aves help in double respiration, act as internal cooling agents and provide buoyancy.

3. What is metagenesis? Mention an example which exhibits this phenomenon.

Ans. Alternation of two diploid generations is called **metagenesis**. It is found in *Obelia* (a coelenterate).

4. What is role of feathers?

Ans. Wing feathers help in flight; Tail feathers act as steering organ while body feathers insulate the body to conserve the body heat.

5. Which group of chordates possess sucking and circular mouth without jaws?

Ans. Class Cyclostomata e.g. *Petromyzon* (sea lamprey)

6. Give one example each for an animal possessing placoid scales and that with cycloid scales.

Ans. **(i)** Cartilage fishes have placoid scales e.g. *Scoliodon* (Dog fish).

(ii) Many bony fishes have cycloid scales e.g. *Labeo* (Rohu).

7. Mention two modifications in reptiles required for terrestrial mode of life.

Ans. **(i)** Non-glandular skin covered with epidermal scales.

(ii) Shelled, polylecithal and cledoic egg.

8. Mention one example each for animals with chitinous exoskeleton and those covered by a calcareous shell.

Ans. **(i)** Chitinous exoskeleton is found in Arthropods e.g. Cockroach.

(ii) Calcareous shell is present in most of molluscs e.g. *Pila* (Pond snail).

9. What is the role of radula in molluscs?

Ans. Radula is a **rasping and masticatory structure** found in buccal mass of gut of most of molluscs.

10. Name the animal which exhibits the phenomenon of bioluminescence. Mention the phylum to which it belongs.

Ans. Bioluminescence (living organism emits light) is found in *Pleurobrachia*. It is found in Phylum **Ctenophora.**

11. Write one example each of the following in the space provided:

(a) Cold-blooded animal .....

(b) Warm-blooded animal .....

(c) Animal possessing dry and cornified skin .....

(d) Dioecious animal .....

Ans. (a) Frog; (b) Mammals e.g. Man; (c) Reptiles e.g. wall lizard; (d) Cockroach, frog, etc.

12. Differentiate between a diploblastic and a triploblastic animal.

Ans. **Diploblastic animals** are formed from two germ layers of gastrula i.e. Ectoderm and Endoderm e.g. Sponges (e.g. **Sycon**) and coelenterates (e.g. *Obelia*, *Hydra*, etc.).

Triploblastic animals are formed from three germ layers of gastrula i.e. Ectoderm, Mesoderm and Endoderm e.g. from flatworms to mammals.

13. Give an example of the following:

(a) Round worm

(b) Fish possessing poison sting

(c) A limbless reptile/amphibian

(d) An oviparous animal.

Ans. **(a)** *Ascaris lumbricoides*

(b) *Trygon* (sting ray)

(c) Snakes are limbless reptiles e.g. *Python*; *Ichthyophis* (Caecilian) is limbless amphibian.

(d) Birds are oviparous animals e.g. *Columba* (Pigeon)

14. Provide appropriate technical term in space provided:

(a) Blood-filled cavity in Arthropoda .....

(b) Free floating form of Cnidaria .....

(c) Stinging organ of jelly fishes .....

(d) Lateral appendages in aquatic annelids .....

Ans. **(a)** Haemocoel; (b) Medusa; (c) Cnidoblasts; **(d)** Parapodia.

15. Match the following :

Animal	Locomotory organ
(a) Octopus	(i) Limbs
(b) Crocodile	(ii) Comb plates
(c) *Catla*	(iii) Tentacles
(d) *Ctenoplana*	(iv) Fins

Ans. (a) (iii) (b) (i) (c) (iv) (d) (ii).

C. SHORT ANSWER TYPE QUESTIONS

1. Differentiate between:

(a) Open circulatory system and closed circulatory system.

(b) Oviparous and viviparous animals.

(c) Direct development and indirect development.

Ans.

(a)

Character	Open circulatory system	Closed circulatory system
1. Definition	Blood comes out of blood vessels in spaces called **sinuses.**	Blood remains inside the blood vessels.
2. Speed and pressure of blood	Blood flows at low speed and at low pressure.	Blood flows at faster speed and at high pressure.
3. Occurrence	In arthropods and molluscs.	Most of annelids and all vertebrates.

(b) Refer Table 5 of the chapter.

(c)

Character	Direct development	Indirect development
1. Definition	Development involves no larval stage.	Development includes a larval stage.
2. Example	Frog (with tadpole larva).	Birds and Mammals.

2. Sort out the animals on the basis of their symmetry (radial or bilateral):

(a) Coelenterates (b) Ctenophores
(c) Annelids (d) Arthropods and
(e) Echinoderms

Ans. (a) Coelenterates with biradial symmetry.
(b) Ctenophores with biradial symmetry.
(c) Annelids with bilateral symmetry.
(d) Arthropods with bilateral symmetry.
(e) Echinoderms with radial symmetry.

3. There has been an increase in number of chambers in heart during evolution of vertebrates. Give the names of class of Vertebrata having two, three or four-chambered heart.

Ans. (a) Classes of vertebrates with two-chambered heart:
Cyclostomata (sea lamprey), **Chondrichthyes** (cartilage fishes) and **Osteichthyes** (Bony fishes).
(b) Classes of vertebrates with three-chambered heart:
Amphibia (e.g. frog) and **Reptilia** (e.g. lizards and snakes).
(c) Classes of vertebrates with four-chambered heart:
Aves (e.g. Crow, Pigeon) and **Mammalia** (e.g. Man).

4. Fill up the blank spaces appropriately:

Phylum/ Class	Excretory Organ	Circulatory Organ	Respiratory Organ
Arthro-poda	A	B	Lungs/Gills/ Tracheal system
C	Nephridia	Closed	Skin/ parapodia
D	Metan-ephridia	Open	E
Amphibia	F	Closed	Lung

Ans. A = Malpighian tubules/Antennary or green glands/coxal glands;
B = Open; **C** = Annelida; **D** = Mollusca;
E = Gills/Pulmonary sac; **F** = Kidneys.

5. Match the following:

(a) Amphibia	(i) Air bladder
(b) Mammals	(ii) Cartilaginous notochord
(c) Chondrichthyes	(iii) Mammary glands
(d) Osteichthyes	(iv) Pneumatic bones
(e) Cyclostomata	(v) Dual habitat
(f) Aves	(vi) Sucking and circular mouth without jaws

Ans. (a) - (v); (b) - (iii); (c) - (ii); (d) - (i); (e) - (vi); (f) - (iv).

6. Endoparasites are found inside the host body. Mention the special structures, possessed by these and which enables them to survive in those conditions.

Ans. (i) Body covered by a tough and resistant **cuticle**.
(ii) Presence of some **adhesive structures** like suckers, hooks, etc.
(iii) Reduction or absence of gut and absorption of nutrients through their body surface.
(iv) Simplified sense organs.

7. Match the following and write correct choice in the space:

Animal	Characteristics
(a) *Pila*	(i) Jointed appendages
(b) Cockroach	(ii) Perching
(c) *Asterias*	(iii) Water vascular system
(d) *Torpedo*	(iv) Electric organ
(e) Parrot	(v) Presence of shell
(f) Dog fish	(vi) Placoid scales

(a) ..... ; (b) ..... ;
(c) ..... ; (d) ..... ;
(e) ..... ; (f) ..... .

Ans. (a) - (v); (b) - (i); (c) - (iii); (d) - (iv); (e) - (ii); (f) - (vi).

8. Differentiate between:

(a) Acoelomate and pseudocoelomate.
(b) Notochord and nerve cord.
(c) Polyp and medusa.

Ans. (a) **Acoelomate** animals are with no coelom e.g. sponges, coelenterates and flatworms; while **pseudocoelomates** have a false coelom called **pseudocoel** filled with a watery fluid e.g. members of phylum Aschelminthes e.g. *Ascaris* (Round worm).
(b) **Notochord** is a solid and unjointed rod of vacuolated cells present on dorsal side above the gut atleast in some stage of development in all the chordates; while **nerve cord** is the narrow and tubular part of CNS present above the notochord.
(c) **Polyp** is the fixed and nutritive zooid of *Obelia* colony; while **medusa** is a free-swimming and reproductive zooid of *Obelia* colony.

9. Give the characteristic features of the following citing one example of each:

(a) Chondrichthyes and osteichthyes.
(b) Urochordata and cephalochordata.

Ans. (a) **Chondrichthyes** is characterised by: Always marine; ventral mouth; cartilagenous endoskeleton; uncovered gill slits; an exoskeleton of placoid scales; two-chambered heart; ureotelic excretion; cold-blooded nature; etc.
e.g. *Scoliodon* (Dog fish)
Osteichthyes is characterised by : Fresh-water or marine; terminal mouth; endoskeleton mostly bony; operculated gill slits; exoskeleton of cycloid scales; two-chambered heart; presence of air bladder; mostly ammonotelic excretion; cold-blooded nature.
e.g. *Labeo* (Rohu) and *Hippocampus* (sea horse).

(b) **Urochordata** is characterised by: Marine habitat; body covered by a test of tunicine; notochord only in tail of larva; undergo retrogressive metamorphosis; etc. e.g. *Ascidia*, *Herdmania*, etc.

Cephalochordata is characterised by: Marine habitat, notochord extends from head to tail region and persists throughout life; unpaired fins present; etc. e.g. *Branchiostoma* (*Amphioxus* - lancelet).

10. Mention two similarities between:

(a) Aves and mammals.

(b) A frog and crocodile.

(c) A turtle and *Pila*.

Ans. (a) Both Aves and Mammals have **4**-chambered heart and lungs for respiration.

(b) Both frog and crocodile are amphibious in habitat; carnivorous in nutrition and oviparous in breeding.

(c) Both turtle and *Pila* are amphibious in habitat and body externally covered by a shell.

11. Name:

(a) A limbless animal

(b) A cold blooded animal

(c) A warm blooded animal

(d) An animal possessing dry and cornified skin

(e) An animal having canal system and spicules

(f) An animal with cnidoblasts

Ans. (a) Python, Naja (snakes); **(b)** Frog and Toad;

(c) Pigeon and man; **(d)** Lizard-*Hemidactylus*

(e) Sycon (sponge); **(f)** *Obelia* (a coelenterate)

12. Give an example for each of the following:

(a) A viviparous animal

(b) A fish possessing a poison sting

(c) A fish possessing an electric organ

(d) An organ, which regulates buoyancy

(e) Animal, which exhibits alternation of generation

(f) Oviparous animal with mammary gland

Ans. (a) Kangaroo and Human female;

(b) *Trygon* (sting ray);

(c) *Torpedo* (Electric ray);

(d) Air or swim bladder in bony fishes

(e) *Obelia* shows metagenesis;

(f) *Ornithorhynchus* (Duck-billed platypus)

13. Excretory organs of different animals are given below. Choose correctly and write in the space provided:

Animal	Excretory Organ/Unit
(a) *Balanoglossus*	(i) Metanephridia
(b) Leech	(ii) Nephridia
(c) Locust	(iii) Flame cells
(d) Liver fluke	(iv) Absent
(e) Sea urchin	(v) Malpighian tubule
(f) *Pila*	(vi) Proboscis gland

(a) ..... ; **(b)** ..... ;

(c) ..... ; **(d)** ..... ;

(e) ..... ; **(f)** ..... .

Ans. (a) - (vi); **(b)** - (ii); **(c)** - (v)

(d) - (iii); **(e)** - (iv); **(f)** - (i).

D. LONG ANSWER TYPE QUESTIONS

1. Give three major differences between chordates and non-chordates and draw a schematic sketch of a chordate showing those features.

Ans. Hints:

Compare notochord, central nervous system and gill slits.

- Refer Table 15 of the chapter
- Refer Fig. 19 of the chapter.

2. What is the relationship between germinal layers and the formation of body cavity in case of coelomates, acoelomates and pseudocoelomates?

Ans. (a) In acoelomates, either there is no mesoderm and coelom between ectoderm and endoderm e.g. **sponges** and **coelenterates**; or a solid mesodermal parenchyma is present between the two e.g. **flatworms.**

(b) In **pseudocoelomates** e.g. roundworms, coelomic pouches are scattered in the mesoderm but no continuous cavity is present.

(c) In **eucoelomates**, a mesodermal-lined body cavity, called **coelom**, is present between the body wall and gut wall. It is formed either by splitting of mesoderm e.g. **schizocoelic coelom** in annelids, arthropods and molluscs; or from enterocoelic pouches of archenteron e.g. **enterocoelic coelom** in echinoderms, hemichordates and chordates.

3. Comment upon the habitats and external features of animals belong to class Amphibia and Reptilia.

Ans.

Characters	Amphibia	Reptilia
1. Habitat	Amphibious.	True terrestrial.
2. Skin	Thin, glandular, vascular and respiratory.	Dry, non-glandular and cornified.
3. Ekoskeleton	Absent.	Of Epidermal scales.
4. Limbs	2 pairs but absent in caecilians. Nails or claws are absent.	2 pairs but absent in snakes. Claws present in lizards.
5. Body parts	Two (head and trunk) or three parts but neck never present.	Four parts: Head, neck, trunk and tail.
6. Mouth	Wide due to carnivorous diet.	Wide due to carnivorous diet.
7. Ear	Tympanum present on head as no ear canal present.	Tympanum lies at the base of pit like ear canal.
8. Webs	Present between digits in many amphibians e.g. frog.	Absent in most of reptiles.
9. Examples	Caecilians, frog, toad, etc.	Turtle, tortoise, lizards, snakes, crocodiles, etc.

4. Mammals are most adapted among the vertebrates. Elaborate.

Ans. Due to presence of following characteristics, mammals are most adapted and successful vertebrates.
Refer page no. 51 of the chapter.

HOTS Higher Order Thinking Skills & Brain Twisting

QUESTIONS WITH ANSWERS

Very Short Answer Questions *One mark each*

1. All the chordates are not vertebrates. Why ?

Ans. Protochordates like *Herdmania* and *Amphioxus* are such chordates which do not have vertebral column.

2. *Herdmania* does not has most of chordate characters in adult stage. Then why it is placed in phylum Chordata ?

Ans. Because the notochord, tail and dorsal hollow nervous system are present in its Ascidian tadpole larva but are lost during retrogressive metamorphosis.

3. Nematodes are called Pseudocoelomates. Why ?

Ans. Because their body cavity is not lined by mesoderm and is called pseudocoel.

4. Why no amphibian is marine in habitat ?

Ans. Because their skin is thin, moist, vascular and glandular for cutaneous respiration so an amphibian in sea water will be dehydrated due to exosmosis in sea water.

5. How the frog and lizards tolerate extreme winter days ?

Ans. These are poikilothermal animals so undergo hibernation during extreme winter days.

6. What is haemocoel ?

Ans. A blood filled body cavity is called **haemocoel.** It is found in arthropods and molluscs.

7. Why the arthropods are most successful and maximum in number ?

Ans. Due to presence of sclerotized exoskeleton.

8. Give one difference between flame cells and nephridia.

Ans. Flame cells are excretory structures of flat worms, while nephridia are excretory organs of annelids.

9. Define metameric segmentation. In which group of animals it is found ?

Ans. When external body divides into metamers by ring-like grooves, called **annuli**, correspond with internal division of coelom by septa, is called metameric segmentation e.g. In annelids.

10. Name the respiratory organs of insects, prawns and king crab.

Ans. **Trachea** in insects. **Gills** in prawns and Book gills in king crab.

Short Answer Questions *Two marks each*

1. Differentiate between protostomes and deuterostomes.

Ans. In protostomes (e.g. annelids, arthropods and molluscs), blastopore forms mouth before development of anus, while in deuterostomes (e.g. vertebrates) blastopore forms anus before development of mouth.

2. Name the excretory organs of flatworms, round worms, annelids and insects.

Ans. Protonephridia or flame cells; Rennet cell, Nephridia and malpighian tubules.

3. Earthworm is hermaphroditic animal but always undergoes cross fertilization. Why ?

Ans. Earthworms shows cross fertilization due to protandrous condition.

4. Differentiate between poikilothermal and homeothermal animals.

Ans. Refer table – 6 of chapter – 4

5. Enlist four peculiar characters of Coelenterata.

Ans.
- Cnidoblasts in epidermis of body wall.
- Gastrovascular cavity or coelenteron.
- Tissue organization
- Development generally includes planula larva.

6. Differentiate between insects and spiders.

Ans. Refer table – 13 of chapter – 4

7. Enlist four peculiar characters of birds.

Ans.
- Fore limbs modified into wings.

- Body covered by a feathery exoskeleton.
- Air cavities (pneumaticity) in the bones for flight.
- Presence of beak but absence of teeth.

8. Tabulate four differences between cartilage and bony fishes.

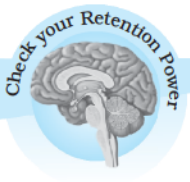
Ans. Refer Table – 20 of chapter – 4.

Short Answer Questions *Three marks each*

1. Discuss types of coelom found in members of kingdom Animalia.
2. Enlist six characters of phylum Annelida. Give three examples.
3. Write down six characters of phylum Mollusca. Give three examples.
4. Discuss six characters of class Reptilia. Enlist three examples.
5. Write the class /phylum to which the following animals belong giving one reason for it :
   (i) *Euplectella* (ii) *Nereis* (iii) Great white shark
6. Enlist six characters of Cyclostomata. Give two examples.

Long Answer Questions *Five marks each*

1. Enumerate the following characters in the animals :
   (i) Symmetry
   (ii) Body temperature.
2. Enlist the characteristics of phylum mollusca and give four examples.
3. Enlist the characteristics of class mammalia and give four examples.
4. State peculiar features of following animals :
   (i) *Ornithorhynchus* (Duck billed platypus)
   (ii) *Balanoglossus* (tongue worm)
   (ii) *Pavo* (Peafowl)
   (iv) *Crocodilus* (crocodile)
   (v) *Peripatus* (walking worm)



QUICK MEMORY TEST

A. Say True or False

Write 'True' or 'False':

1. Whale is largest fish known.
2. Ungulates include cud-chewing animals.
3. *Rhinoceros* is an even-hoofed mammals.
4. Cartilaginous fish have gill cover.
5. Spiders have 6 pairs of appendages.
6. Flatworms have true coelom.
7. Sponges have tube-within-a-tube body plan.
8. Snails and slugs have open circulatory system.
9. Pseudocoel is found in flatworms and roundworms.
10. Housefly has sponging mouth parts while mosquito has piercing-sucking mouth parts.
11. Tornaria is the larva of echinoderms while bipinnaria is the larva of Hemichordates.
12. Aristotle's lantern is a masticatory apparatus of echinoids.
13. Cephalothorax is formed only in crustaceans.
14. *Sacculina* causes parasitic castration in the crabs.
15. Smallest mammal is water shrew while tallest mammal is giraffe.
16. *Eudynamis* builds a fancy nest.
17. *Archaeopteryx* is a connecting link.
18. Kiwi is the smallest flightless bird.

19. Millipedes possess 70 to 100 pairs of legs.
20. The body of the molluscs is hard but is covered by a soft shell.
21. The fertilization in majority of echinoderms occurs in open water.
22. The echinoderms donot show any fundamental similarities with chordates.
23. Cartilage fishes are marine, have placoid scales and homocercal tail fin.
24. Protostomic plan is observed in annelids, arthropods and molluscs.
25. Frog has 10 pairs and man has 12 pairs of cranial nerves.

B. Complete the missing links

1. Radial symmetry means that the body of the animal may be divided into ..... equal halves.
2. Animals with three primary germinal layers are referred to as ..... .
3. Sponges have a body plan named as ..... .
4. Animals without coelom are termed as ..... .
5. Roundworms are with body plan known as ..... .
6. The success of arthropods on land is due to ..... .
7. The excretion in insects is by ..... .
8. Fishes with cartilaginous endoskeleton belong to class ..... .
9. The lateral line sense organs is to detect ..... .
10. Poisonous snakes possess poisonous teeth for injecting poison are called ..... .
11. Pseudocoelom is found in ..... .
12. ..... and ..... have trochophore larva in their development.
13. The precious marriage gift in Japan is ..... .
14. Sexual phase of *Nereis* is called ..... .
15. Leech stores the sucked blood in ..... .
16. Autotomy and regeneration are peculiar characters of ..... .
17. ..... maintain a water current in the sponges.
18. Syncitial epidermis is found in ..... .
19. Rearing of silkworms is called ..... .
20. Tube feet of echinoderms help in ..... and ..... .
21. Gill slits are covered by operculum in ..... .
22. ..... and ..... are egg-laying mammals.
23. *Balanoglossus* belongs to ..... .
24. Squirrels have chisel-like incisors for ..... .
25. The distinctive feature of Primata is ..... .
26. The structure which separates the thoracic cavity from abdominal cavity in mammals is ..... .
27. True coelom originated firstly in ..... .
28. A coral reef with a central shallow lake is called ..... .
29. Food storing cells of sponges are called ..... .
30. Biradial symmetry is found in ..... .
31. Botryoidal tissue filled coelom is found in ..... .
32. In ..... of Mollusca, eye structure resembles to that of vertebrates.
33. ..... acts as a connecting link between Annelida and Arthropoda.
34. Largest land animal is ..... while tallest animal is ..... .
35. Duck billed platypus belongs to ..... while kangaroo belongs to ..... .

C. Choose the correct alternative

1. Larva of many annelids is **Trochophore/Glochidium.**
2. Retrogressive metamorphosis is found in ***Amphioxus/Herdmania*.**
3. Metameric segmentation is main feature of **Annelida/Arthropoda.**
4. Caecilians belong to class **Amphibia/Reptilia.**
5. Colloblasts are found only in **coelenterates/ctenophorans.**
6. Internal buds of *Spongilla* are called **Gemmules/Gemmae.**
7. Animals having an in-built thermostat to maintain constant body temperature are called **poikilothermal/homeothermal** animals.

8. Period of dormancy in animals during winter months is called **aestivation/hibernation.**
9. Antennary glands are excretory organs of **cockroach/ prawn.**
10. Blue colour blood of molluscs is due to **haemocyanin/phycocyanin.**
11. Fishes and amphibians are **anamniotes/amniotes.**
12. Copulatory organs claspers are found in males of **cartilage fishes/bony fishes/both cartilage and bony fishes.**
13. Apes found in India is **Gibbon/Chimpanzee /Gorilla.**
14. Choanocytes are peculiar cells found in **ctenophorans/sponges.**
15. Sea horse is a **bony fish/mammal.**

Answers QUICK MEMORY TEST

A. Say True or False

1. False; **2.** True; **3.** False; **4.** False; **5.** True; **6.** False; **7.** False; **8.** True; **9.** False; **10.** True; **11.** False; **12.** True; **13.** False; **14.** True; **15.** True; **16.** False; **17.** False; **18.** True; **19.** True; **20.** False; **21.** True; **22.** False; **23.** False; **24.** True; **25.** True.

B. Complete the missing links

1. Two; **2.** Triploblastic; **3.** Cell-aggregate plan; **4.** Acoelomates; **5.** Tube-within-a-tube plan; **6.** Sclerotized exoskeleton; **7.** Malpighian tubules; **8.** Chondrichthyes; **9.** Changes in water currents; **10.** Fangs; **11.** Nematodes; **12.** Annelids and molluscs; **13.** *Euplectella.* **14.** *Heteronereis;* **15.** Crop; **16.** Echinoderms; **17.** Choanocytes; **18.** Nematodes; **19.** Sericulture; **20.** Locomotion, respiration; **21.** Bony fishes; **22.** *Ornithorhynchus, Tachyglossus;* **23.** Hemichordata; **24.** Gnawing; **25.** Grasping ability as thumb is opposable to remaining digits; **26.** Diaphragm; **27.** Annelids; **28.** Atoll; **29.** Thesocytes; **30.** Sea anemones; **31.** Leeches; **32.** Cephalopods; **33.** *Peripatus;* **34.** Elephant, giraffe; **35.** Prototheria, Metatheria.

C. Choose the correct alternative

1. Trochophore ; **2.** *Herdmania* ; **3.** Annelida ; **4.** Amphibia; **5.** Ctenophorans; **6.** Gemmules; **7.** Homeothermal; **8.** Hibernation; **9.** Prawn; **10.** Haemocyanin; **11.** Anamniotes; **12.** Cartilage fishes; **13.** Gibbon; **14.** Sponges; **15.** Bony fish.

REVISION EXERCISES

Very Short Answer Questions

One mark each

1. Define deuterostomous condition.
2. What is pseudocoel?
3. Name the group and animal acting as connecting link between non-chordates and chordates.
4. Give one example of each : asymmetry, radial and bilateral symmetry.
5. Give one example of each : Acoelomates, Pseudocoelomate and Haemocoelomate.
6. Give one example of each : Diploblastic and triploblastic animals.
7. Name excretory organs of flatworms, annelids and insects.
8. What are hermaphrodite animals?
9. What is retrogressive metamorphosis?
10. Give another term of winter-sleep and summer-sleep.
11. Name a fresh water sponge and a coelenterate.
12. Name the peculiar cell type found in Porifera and Coelenterata.
13. Give the basis on which phylum Coelenterata has been sub-divided.
14. What is polymorphism?
15. Name the free living flatworms.
16. Which larva is found in the members of both Annelida and Mollusca?
17. Which type of mouth parts are found in cockroach, mosquito and house-fly?
18. Name two social and polymorphic insects.
19. List the chordate characters.
20. Name two flightless birds.
21. What are connecting links?
22. Name anti-coagulant in the saliva of leech.

23. Name the connecting link between annelids and arthropods.
24. Name two viviparous fishes.
25. Define metamerism.
26. What are diploblastic and triploblastic animals?
27. Name an animal group with open circulatory system.
28. What are cold blooded animals? Give one example.
29. Define coprophagy.
30. What do you mean by viviparity?
31. Name the larval forms found in the life history of butterflies and house flies.
32. What are the excretory organs of annelids and insects?
33. What is gemmule? Give its function.
34. Give the scientific name of bath sponge.
35. Name the sponge which is used as marriage gift and symbol of union till death.
36. Why is Coelenterata also called Cnidaria?
37. Which type of body organisation is found in the coelenterates?
38. Name the excretory cell of Platyhelminthes.
39. What is apolysis?
40. Define eutyly.
41. What is metameric segmentation?
42. Why does the human blood not clot in the alimentary canal of leech?
43. Define haemocoel.
44. Give one major difference between an insect and a spider.
45. What is osphradium? Give its function.
46. Name the connecting link between Mollusca and Annelida.
47. Which group of animals has stomochord?
48. Give an example of Urchordata and Cephalochordata.
49. Which period is commonly called age of dinosaurs?
50. What are patagia? Give their function.

ANSWERS

1. In this, the blastopore forms anus *e.g.* in echinoderms and chordates; **2.** It is formed from blastocoel and is not lined by peritoneal layers; **3.** Hemichordata, *Balanoglossus*; **4.** *Amoeba*, *Hydra* and a Fish; **5.** Flatworms, Nematodes and Arthropods & Molluscs; **6.** *Hydra* (diploblastic) and *Fasciola* (triploblastic); **7.** Protonephridia, Nephridia and Malpighian tubules; **8.** The animals having both type of sex-organs; **9.** A more advanced larva changes into degenerate adult *e.g.*, *Herdmania*; **10.** Hibernation, aestivation; **11.** *Spongilla*, *Hydra* ; **12.** Collar cell, Cnidoblasts; **13.** On the basis of development of zooids; **14.** When in a colonial organism, different zooids are modified defferently to perform different functions; **15.** Planarians; **16.** Trochophore larva; **17.** Biting & chewing type, piercing-sucking type and sponging type; **18.** Honey bee (*Apis indica*) and Termite (*Microtreme*); **19.** Notochord, gill slits; dorsal & hollow nervous system and tail; **20.** Kiwi and Ostrich; **21.** Organism having characters of two different groups *e.g.*, *Peripatus*; **22.** Hirudin; **23.** *Peripatus*-walking worm; **24.** *Pristis*, *Zygaena*; **25.** Repeatition of internal body parts; **26.** Diploblastic animals develop from two primary germ layers e.g. sponges and coelenterates, while triploblastic animals develop from three primary germ layers e.g. flat worms to mammals; **27.** Arthropoda; **28.** Animals whose body temperature changes with environmental temperature *e.g.* amphibians; **29.** Eating upon faeces *e.g.* pigs; **30.** Give birth to young ones e.g. mammals; **31.** Butterfly = caterpillar larva; housefly = Maggot larva; **32.** Annelida = nephridia, Insect = Malpighian tubules; **33.** Internal buds of fresh-water sponges. These help in dispersal and perennation; **34.** *Euspongia*; **35.** *Euplectella*; **36.** Due to presence of cnidoblasts (stinging cells); **37.** Tissue organisation; **38.** Protonephridia or flame cells; **39.** Shedding of gravid proglottids of tape worm; **40.** Fixed number of cells throughout life *e.g.* in nematodes; **41.** External division of body corresponding with internal division of coelom *e.g.* annelids; **42.** Due to mixing of anticoagulant hirudin with human blood; **43.** False body cavity with blood *e.g.* in arthropods; **44.** Insect has 3 pairs of legs while spider has 4 pairs of legs; **45.** A chemosensory organ of molluscs which tests the nature of ingoing water current; **46.** *Neopilina*; **47.** Hemichordata; **48.** Urochordata = *Herdmania*; Cephalochordata = *Amphioxus*; **49.** Jurassic period of Mesozoic era; **50.** Skin folds in bats. These are supported by fore limbs and help in true flight.

Short Answer Questions

Two marks each

1. Differentiate between exoskeleton and endoskeleton.
2. List unique features of sponges.
3. Why is *Physalia* called a polymorphic animal.
4. Differentiate between sharks and rays.
5. Name the animal groups having tracheae, book gill and book lungs as their respiratory organs.
6. Which animal groups have antennary glands, nephridia and coxal glands as their excretory organs?
7. What is protogynous condition? Give one example.
8. How does progressive metamorphosis differ from retrogressive metamorphosis?

9. List three peculiar characters of Coelenterata.
10. What is marsupium? Give its function.
11. What do you mean by metameric segmentation? Give one example.
12. Why does the blood not clot in the crop of leech?
13. Differentiate between centipede and millipede.
14. What is sexual dimorphism in cockroach?
15. List three characters of phylum Mollusca.
16. List four basic characters of phylum Chordata.
17. List three characters of Insecta.Give one example.
18. List two differences between sharks and rays.
19. Give four peculiar characters of birds.
20. What is peculiar about Prototherians?
21. Name four groups of Eutherians.
22. Write flight adaptations in bats?
23. List aquatic adaptations in whale.
24. Describe the peculiar features of digestive system in a typical bird.
25. Write four salient features of Echinodermata. (*Himachal Board 2008*)
26. Write four salient features of Porifera. (*Himachal Board 2008*)
27. Give four salient features of Arthropoda. (*Himachal Board 2008*)

ANSWERS

1. Refer Table 7 of the chapter 4.
2. Presence of two types of pores : dermal ostia and osculum; cellular organisation; diploblastic; choanocytes or collar cells in the gastral layer; and canal system.
3. Because it has many types of zooids like **tentaculozooids** (for food capturing), **gastrozooids** (for digestion); **gonodendra** (branched blastostyles); **gonophores** (for sexual reproduction); etc.
4. Refer Table 19 of the chapter 4.
5. Insects, king crabs and scorpions;
6. Crustaceans, annelids and arachnids;
7. In this, ovaries mature earlier than testes in a bisexual animal *e.g.*, *Scypha* (Sycon);
8. In progressive metamorphosis (*e.g.*, frog), a young changes into an advanced adult, while in retrogressive metamorphosis (*e.g.*, *Herdmania*), an advanced larva changes into degenerate adult by loss of organs;
9. Presence of tissue - organisation, coelenteron and cnidoblasts;
10. It is a skin pouch present on ventral side of abdomen of female kangaroo in which imperfectly developed young, called **mammary foetus**, is nursed;
11. When external division of body by annuli and internal division of coelom by septa correspond each other *e.g.*, in annelids like earthworm;
12. Blood is mixed with an anticoagulant, called **hirudin**, present in its saliva;
13. Refer Table 12 of the chapter 4.
14. When two sexes of a species are externally different in their structure and function *e.g.*, male cockroach has anal styles but no brood pouch, while female cockroach has brood pouch but no anal style;
15. Soft body, pallium or mantle, and shell;
16. Presence of notochord, gill slits, dorsal and hollow nerve cord, and tail;
17. Body of 3 parts (Head, thorax and abdomen), 3 pairs of legs and tracheal respiration e.g. cockroach;
18. In sharks, gill slits lie on lateral sides of head and pectoral fins are small, while in rays, gill slits lie on ventral side and pectoral fins are large sized;
19. Feathery exoskeleton, fore limbs as wings, pneumatic bones and beak;
20. These are egg-laying mammals and act as connecting links between reptiles and mammals;
21. Insectivorous line, Gnawing mammals (Rodents and lagomorphs), Aquatic mammals (whales, dolphin, etc.) and Elephants, carnivores and ungulates;
22. Flight organs are patagia, pneumatic bones and echolocation;
23. Streamlined body, nostrils shifted above, fore limbs as paddles, tail as steering apparatus, blubber, etc.
24. Digestive system of a bird is formed of : **Mouth bounded by a beak** for feeding (beak is modified differently in different birds according to their feeding habit and may be for seed crushing, fruit scooping, tearing flesh, nectar sipping, wood chiseling, etc.); **no teeth** in buccal cavity (so cannot crush the food); a food-storing thin and distensible **crop;** a food-masticating muscular **gizzard;** a short **rectum** and a 3-chambered **cloaca** (for conservation of water);
25. Presence of spiny skin, water vascular system, locomotion by tube feet and always marine.
26. Presence of porous body, canal system, choanocytes and cellular organisation.
27. Presence of jointed legs, sclerotized exoskeleton, haemocoel and open circulatory system with haemolymph (white coloured blood).

Short Answer Questions

Three marks each

1. Describe characteristic features of chordates.
2. Differentiate between Prototherians, Metatherians and Eutherians.
3. What type of body plan do the following animals have :
   Hydra, Sponge, flatworms, *Ascaris*, jelly-fish, earthworm and spiders?
4. With which animal would you associate the following :
   Carapace, malpighian tubules, medusa, flame cells, mantle, cephalothorax, crop, gizzard?
5. Give three important distinguishing characters of arthropods, reptiles and mammals.
6. Write the general characteristic features of Nemathelminthes.
7. Give three reasons why a snail and *Octopus* are classified under the same phylum.
8. Name the classes in which living vertebrates have been grouped.
9. Write about cartilaginous fishes.
10. Give characteristic features of amphibians.
11. Which of the characters distinguish lizards from the snakes?
12. Give an account of egg-laying mammals and marsupials.
13. List the characters of primates.
14. Justify the statement "Mammals are the most successful and dominant animals today."
15. Differentiate between lizards and snakes.
16. How are the mammals advanced over the reptiles?
17. Differentiate between cartilage and bony fishes.
18. Give peculiar features of Hemichordates. What is their phylogenetic significance?
19. List various types of mouth parts found in different insects.
20. Enlist the unique features of phylum Annelida.

Long Answer Questions

Five marks each

1. List the flight adaptations in the birds.
2. Give the diagnostic features of Mollusca.
3. Differentiate the cartilaginous and bony fishes.
4. Give the diagnostic features of Arthropoda.
5. Give the general characteristics of the vertebrates and list the distinguishing features of different classes under it.
6. Distinguish between :
   (a) Oviparity and Viviparity (b) Marsupials and Placental mammals.
7. (a) Roundworm and Flatworm. (b) Lizard and Snake.
8. Discuss the general characters of class Mammalia.

COMPETITION FILE OBJECTIVE TYPE QUESTIONS

A. MULTIPLE CHOICE QUESTIONS (MCQs):

(From AIPMT & Other Competitive Examinations)

1. Which one of the following is a matching pair of a body feature and the animal possessing it?
   (a) Ventral heart — Scorpion (b) Post-anal tail — *Octopus*
   (c) Ventral central nervous system — Leech (d) Pharyngeal gill slits absent in embryo — *Chameleon*
   (CBSE 2007)
2. What is common between parrot, platypus and kangaroo?
   (a) Oviparity (b) Homeothermy (c) Toothless jaws (d) Functional post–anal tail
   (CBSE 2007)
3. What is true about *Nereis*, scorpion, cockroach and silver fish?
   (a) All belong to same phylum (b) All have jointed paired appendages
   (c) All possess dorsal heart (d) None of them is aquatic *(CBSE 2007)*
4. What is common among silver fish, scorpion, crab and honey bee?
   (a) Compound eyes (b) Poison glands (c) Jointed appendages (d) Metamorphosis
   (AIIMS 2007)

5. Which of the following is not a characteristic feature of all the chordates?
(a) Presence of coelom (b) Pharyngeal gill clefts in early embryos
(c) A diaphragm that separates thorax from abdomen (d) Dorsal nerve cord *(AFMC 2007)*

6. Which one of the following is a unique feature of the mammalian body?
(a) Homeothermy (b) Presence of diaphragm (c) Rib cage (d) Four-chambered heart *(Manipal 2007)*

7. Animals have the innate ability to escape from predation. Examples for the same are given below. Select the incorrect example :
(a) Enlargement of body size by swallowing air in puffer fish (b) Melanism in moths
(c) Poison fangs in snakes (d) Colour change in chameleon *(JIPMER 2007)*

8. In contrast to the annelids, the platyhelminthes show :
(a) Radial symmetry (b) Presence of pseudocoel (c) Bilateral symmetry (d) Absence of body cavity *(JIPMER 2007)*

9. Haemocoel is found in :
(a) *Hydra* and *Aurelia* (b) *Taenia* and *Ascaris*
(c) Cockroach and *Pila* (d) *Balanoglossus* and *Herdmania* *(BVP 2007)*

10. The group of Anamniotes includes :
(a) Reptiles and birds (b) Birds and mammals
(c) Reptiles and mammals (d) Fish and amphibians *(BVP 2007)*

11. The excretory matter of bony fish is :
(a) Urea (b) Protein (c) Ammonia (d) Amino acid *(BVP 2007)*

12. Study of reptiles is known as :
(a) Serpentology (b) Herpotology (c) Ichthyology (d) None of these *(Haryana PMT 2007)*

13. Identify a deuterostome :
(a) *Leucosolenia* (b) *Dentalium* (c) *Dugesia* (d) *Ophiothrix* *(Haryana PMT 2007)*

14. Isinglass, a type of by-product of fish industry, is used for :
(a) Production of insulin (b) Feeding cattle, pigs and poultry
(c) Clarification of vinegar, wines and beer (d) Preparation of paints and varnishes *(Haryana PMT 2007)*

15. Which of the following is an egg-laying mammal?
(a) Whale (b) Platypus (c) Penguin (d) Kangaroo *(Haryana PMT 2007)*

16. Book lungs are respiratory organs in :
(a) Scorpion (b) Prawn (c) Snail (d) Cockroach *(Haryana PMT 2007)*

17. The post anal tail is present in :
(a) Chordates (b) Vertebrates (c) Invertebrates (d) All of them *(KCET 2007)*

18. Find the odd example :
(a) Sea lily (b) Sea fan (c) Sea cucumber (d) Sea urchin *(KCET 2007)*

19. **Statement A :** All metatherians are placental mammals.
Statement B : All placental mammals have menstrual cycle.
(a) Statement A is true and statement B is false (b) Statement A is false and statement B is true
(c) Both the statements A and B are true (d) Both the statements A and B are false *(KCET 2007)*

20. The radial symmetry is observed in :
A. Platyhelminthes B. Coelenterates C. Aschelminthes D. Annelids E. Echinoderms
(a) B, C and E only (b) A, B, C and E only (c) B, C and A only
(d) A, C and E only (e) B and E only *(Kerala PMT 2007)*

21. Which one of the following is not a characteristic feature of subphylum Vertebrata?
(a) Dorsal tubular nerve cord (b) Ventral muscular heart
(c) Presence of notochord in adult (d) Presence of kidneys
(e) Two pairs of lateral appendages (fins or limbs) *(Kerala PMT 2007)*

22. Which one of the following is correctly paired?
(a) *Trygon* = monitor (b) *Ichthyophis* = crow (c) *Varanus* = sting ray
(d) *Corvus* = limbless amphibian (e) Pristis = saw fish *(Kerala PMT 2007)*

23. In molluscs, eye is present on the tip of a stalk called :
(a) Osphradium (b) Ostracum (c) Ommatophore (d) Operculum *(CPMT 2007)*

24. Which of the following has exoskeleton of scales and paired copulatory organs?
(a) Sharks (b) Lizards (c) Urodeles (d) Urochordates *(CPMT 2007)*

25. *Daphnia* is commonly known as :
(a) Clam shrimp (b) Fairy shrimp (c) Tadpole shrimp (d) Water fleas *(CPMT 2007)*

26. Which of the following characters are present in class Crustacea?
(a) Cephalothorax, gills and appendages (b) Head, thorax, gills and appendages
(c) Cephalothorax, book gills and appendages (d) Head, thorax, book gills and appendages *(CPMT 2007)*

27. Canal system is a characteristic of :
(a) *Hydra* (b) Sponges (c) *Ascaris* (d) None of these
(Orissa JEE 2007)

28. Haemocoel is found in :
(a) Echinoderms (b) Sponges (c) Arthropods (d) Annelids *(Orissa JEE 2007)*

29. *Chamaeleon* is a / an :
(a) Arthropod (b) Reptile (c) Amphibian (d) Bird *(Orissa JEE 2007)*

30. Scyphozoan medusa is more commonly known as ;
(a) Sea urchin (b) Sea pen (c) Sea fur (d) Jelly fish *(Orissa JEE 2007)*

31. In which of the following animals, notochord is not present?
(a) Adult tunicate (b) *Branchiostoma* (c) *Myxine* (d) *Balanoglossus*
(Orissa JEE 2007)

32. Which of the following phyla has largest number of species?
(a) Arthropoda (b) Annelida (c) Coelenterata (d) Echinodermata
(Orissa JEE 2007)

33. Mouth parts of mosquitoes are adapted for :
(a) Chewing (b) Sucking (c) Sponging (d) Biting *(Orissa JEE 2007)*

34. Which one of the following is not a characteristic of Phylum Annelida?
(a) Pseudocoelom (b) Ventral nerve cord (c) Segmentation (d) Closed circulatory system
(CBSE 2008)

35. Which one of the following is correctly matched with its two general characteristics?
(a) Echinodermata : Pentamerous radial symmetry and mostly internal fertilization
(b) Mollusca : Normally oviparous and development through a trocophore or velliger larva
(c) Arthropoda : Body divided into head, thorax and abdomen, and respiration by tracheae
(d) Chordata : Notochord at some stage and, separate anal and urinary openings *(CBSE 2008)*

36. Which one of the following groups of three animals each is correctly matched with their one characteristic morphological feature?

Animals	Morphological features
(a) Scorpion, spider, cockroach, ...	Ventral solid central nervous system
(b) Cockroach, locust, *Taenia*	Metameric segmentation
(c) Liver fluke, sea anemone, sea cucumber	Bilateral symmetry
(d) Centipede, prawn, sea urchin	Jointed appendages

(CBSE 2008)

37. *Ascaris* is characterised by :
(a) Presence of true coelom but absence of metamerism (b) Presence of true coelom and metamerism
(c) Absence of true coelom and presence of metamerism (d) Presence of neither true coelom nor metamerism
(CBSE 2008)

38. The animals with bilateral symmetry in young stage, and radial pentamerous symmetry in the adult stage belong to the phylum :
(a) Annelida (b) Mollusca (c) Cnidaria (d) Echinodermata
(AFMC 2008)

39. Biradial symmetry and lack of cnidoblasts are the characteristics of :
(a) Starfish and sea anemone (b) *Ctenoplana* and *Bereo* (c) *Aurelia* and *Paramecium* (d) *Hydra* and Starfish
(AFMC 2008)

40. Polyp phase is absent in :
(a) *Hydra* (b) *Aurelia* (c) *Physalia* (d) *Obelia* (***BHU 2008***)

41. Among the following, colonial insects are :
(a) Locusts (b) Mosquitoes (c) White ants (d) Bugs (***BHU 2008***)

42. Which one of the following animals is correctly matched with its one characteristic and the taxon?

Animal	Characteristic	Taxon
(a) Millipede	Ventral nerve cord	Arachnida
(b) Duck billed platypus	Oviparous	Mammalian
(c) Silver fish	Pectoral and pelvic fins	Chordate
(d) Sea anemone	Triploblastic	Cnidaria

(***AIIMS 2008***)

43. In which of the following phyla, while the adult shows radial symmetry, the larva shows bilateral symmetry?
(a) Annelida (b) Arthropoda (c) Mollusca
(d) Echinodermata (e) Porifera (***Kerala PMT 2008***)

44. In which of these animals, antennary glands function as excretory organs?
(a) Human being (b) Cockroach (c) *Planaria*
(d) Prawn (e) Earthworm (***Kerala PMT 2008***)

45. Which of the following animals is unisexual?
(a) Tapeworm (b) Leech (c) Sponge
(d) Earthworm (e) Cockroach (***Kerala PMT 2008***)

46. In which of the following organisms, Malpighian tubules are found?
(a) Honey bee (b) Frog (c) *Ascaris* (d) Rabbit (***Orissa JEE 2008***)

47. ..... type of eyes are found in the insects :
(a) Camera eye (b) Red eye (c) Normal eye (d) Compound eye
(***Orissa JEE 2008***)

48. Larva of jelly fish (*Aurelia*) is :
(a) Planula (b) Polyp (c) Medusa (d) Blastula (***Orissa JEE 2008***)

49. Poikilotherms are also known as :
(a) Isotherms (b) Ectotherms (c) Endotherms (d) Heterotherms
(***Orissa JEE 2008***)

50. Instead of teeth, baleen (hanging horny plates in mouth) are found in :
(a) Blue whale (b) Shark (c) Dolphin (d) *Archaeopteryx*
(***Orissa JEE 2008***)

51. Highest degree of polymorphism is found in :
(a) Protozoa (b) Cnidaria (c) Platyhelminthes (d) Arthropoda
(***J & K CET 2008***)

52. Sea mouse belongs to phylum :
(a) Mollusca (b) Cnidaria (c) Arthropoda (d) Annelida
(***J & K CET 2008***)

53. Which one of the following animals belongs to Cyclostomata?
(a) *Channa* (b) *Loris* (c) *Dodo* (d) Petromyzon
(***J & K CET 2008***)

54. An egg laying mammal is :
(a) *Didelphis* (b) *Macaca* (c) *Ornithorhynchus* (d) *Macropus*
(***J & K CET 2008***)

55. In sharks, one of the following is absent :
(a) Claspers (b) Placoid scales
(c) Cartilaginous endoskeleton (d) Air bladder (***J & K CET 2008***)

56. Comb plates are found in :
(a) *Adamsia* (b) *Aurelia* (c) *Nereis* (d) *Pleurobrachia*
(***J&K CET 2008***)

57. In echolocation, the animal that produces high frequency sound is :
(a) Monkey (b) Butterfly (c) Bat (d) Squirrel (***J&K CET 2008***)

58. In which triploblastic animal, coelom is absent?
(a) Platyhelminthes (b) Aschelminthes (c) Annelids (d) Arthropods (*WB JEE 2008*)

59. 'Royal Jelly' is secreted from :
(a) Hypopharyngeal gland (b) Salivary gland (c) Milk gland (d) Skin glands (*WB JEE 2008*)

60. A waxy substance secreted by honey bee to repair combs is called :
(a) Propolis (b) Honey dew (c) Nectar (d) Sporopollenin (*WB JEE 2008*)

61. Which one of the following groups of animals is bilaterally symmetrical and triploblastic :
(a) Coelenterates (Cnidarians) (b) Aschelminthes (Roundworm)
(c) Ctenophores (d) Sponges (*CBSE 2009*)

62. Which one of the following pairs of animals comprises "jawless fishes"?
(a) Lampreys and eels (b) Mackerals and rohu
(c) Lampreys and hag fishes (d) Guppies and hag fishes (*CBSE 2009*)

63. *Peripatus* is a connecting link between :
(a) Ctenophora and Platyhelminthes (b) Mollusca and Echinodermata
(c) Annelida and Arthropoda (d) Coelenterata and Porifera (*CBSE 2009*)

64. Phylum Protozoa is classified on the basis of :
(a) Mode of reproduction (b) Locomotory organelles
(c) Mode of nutrition (d) None of these (*AFMC 2009*)

65. Book lungs are respiratory organs of :
(a) Mollusca (b) Mammals (c) Arachnida (d) Earthworm (*AFMC 2009*)

66. Venom of cobra attacks :
(a) Digestive system (b) Immune system (c) Nervous system (d) Circulatory system (*AFMC 2009*)

67. Which of the following is most poisonous?
(a) *Chameleon* (b) Glass snake (c) *Heloderma* (d) Horn toad (*AFMC 2009*)

68. Which of the following is a connecting link between mammals and reptiles?
(a) *Peripatus* (b) *Balanoglossus* (c) *Ornithorhynchus* (d) *Archaeopteryx* (*AFMC 2009*)

69. Ephyra is the stage in the life cycle of :
(a) *Physalia* (b) *Obelia* (c) Sea anemone (d) *Aurelia* (*AFMC 2009*)

70. Egg of reptiles and birds is :
(a) Mesolecithal (b) Telolecithal (c) Polylecithal (d) Alecithal (*CPMT 2009*)

71. Tube feet are locomotory organs of :
(a) Spider (b) Reptile (c) Starfish (d) Cat fish (*CPMT 2009*)

72. Tissues are absent from the body of :
(a) Sponges (b) Annelida (c) Platyhelminthes (d) Arthropoda (*CPMT 2009*)

73. Worker bees are :
(a) Fertile females (b) Sterile females
(c) When queen is absent then act as queen (d) Sterile drones (*CPMT 2009*)

74. Which of the following feature is not common between newt and *Hemidactylus*?
(a) Body is divisible into head, neck, trunk and tail (b) Heart is 3-chambered
(c) Head has one pair of eyes and tympanic membrane (d) Trunk has two pairs of limbs (*CPMT 2009*)

75. Which one of the following mammals, is not an odd-toad ungulate?
(a) Rhinoceros (b) Camel (c) Zebra (d) Horse (*DPMT 2009*)

76. All flatworms differ from all round worms in having?
(a) Triploblastic body (b) Solid mesoderm (c) Bilateral symmetry (d) Metamorphosis (*DPMT 2009*)

77. The snake eating snake is :
(a) Black cobra (b) King cobra (c) Rattle snake (d) Anoconda (*J&K-CET 2009*)

78. The second largest aquatic vertebrate is :
(a) Blue whale (b) Whale shark (c) Sea elephants (d) Dugongs (*J&K-CET 2009*)

79. Limbless amphibians are called :
(a) Paddle worms (b) Glow worms (c) Caecilians (d) Pin worms (*J&K-CET 2009*)

80. The second largest phylum in animal kingdom is :
(a) Annelida (b) Arthropoda (c) Chordata (d) Mollusca ***(J&K-CET 2009)***

81. Siphonophora is the order in :
(a) Protozoa (b) Cnidaria (c) Porifera (d) Annelida ***(J&K-CET 2009)***

82. Choanocytes form the lining of paragastric cavity in :
(a) Jelly fishes (b) Sponges (c) Helminthes (d) Echinoderms ***(J&K-CET 2009)***

83. Which of the following shows polymorphism?
(a) *Physalia* (b) *Trypanosoma* (c) Termite (d) All of these ***(BVP 2009)***

84. Secondary radial symmetry is found in :
(a) Cnidaria (b) Jelly fish (c) Echinodermata (d) Hemichordata ***(BVP 2009)***

85. Connecting link between Annelida and Mollusca is :
(a) *Peripatus* (b) *Lepidosiren* (c) *Neopilina* (d) *Protopterus* ***(BVP 2009)***

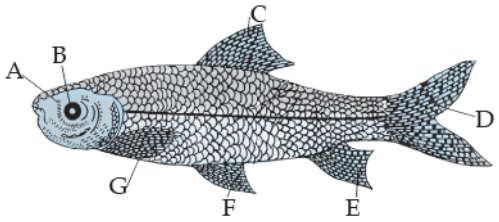
86. Bilateral symmetry, metameric segmentation, coelom and open circulatory are features of :
(a) Annelida (b) Arthropoda (c) Mollusca (d) Echinodermata ***(BVP 2009)***

87. Correctly matched set of Phylum, Class and Example is :
(a) Mollusca — Bivalvia — *Pinctada* (b) Protozoa — Mastigophora — *Entamoeba*
(c) Arthropoda — Diplopoda — *Scolopendra* (d) Chordata — Cyclostomata — *Phrynosoma* ***(BVP 2009)***

88. Crocodile and penguin are similar to whale and dogfish in which of the following features?
(a) Possess a solid single stranded central nervous system (b) Lay eggs and guard them till they hatch
(c) Passess bony skeleton (d) Have gill slits at some stage ***(CBSE 2010)***

89. How do you differentiate a butterfly from a moth?
(a) Moth has feathery antennae but butterfly has club-shaped antennae
(b) Moth has one pair of wings but butterfly has two pairs of wings
(c) Moth is diurnal but butterfly is nocturnal
(d) Moth has simple eyes but butterfly has compound eyes ***(KCET 2010)***

90. The diagram of *Labeo rohita* is given below. Identify the parts labelled A, B, C, D, E, F, G.



	A	B	C	D	E	F	G
(a)	Stimulus	Receptor	Sensory nerve	Motor nerve	Effector	Pectoral fin	Pelvic fin
(b)	Nostril	eye	Anal fin	Caudal fin	Dorsal fin	Pectoral fin	Pelvic fin
(c)	Nostril	eye	Dorsal fin	Caudal fin	Anal fin	Pelvic fin	Pectoral fin
(d)	Nostril	eye	Dorsal fin	Caudal fin	Pectoral fin	Anal fin	Pelvic fin

(KCET 2010)

91. Which of the following match is correct?
(a) Cockroach – Crustacea (b) *Pila* – Pelecypoda
(c) Spider – Arachnida (d) *Unio* – Gastropoda ***(UP-CPMT 2010)***

92. Which of the following is not a character of chordates?
(a) Ventral nerve cord (b) Rod-like notochord (c) Pharyngeal gill slits (d) Bilateral symmetry ***(UP-CPMT 2010)***

93. Choanocytes are found in :
(a) Protozoa (b) Porifera (c) Coelenterata (d) Ctenophora ***(UP-CPMT 2010)***

94. Which of the following statements is correct regarding cockroach?
(a) Ventral nerve cord (b) Spiracles help in excretion
(c) Phallomere is present in female cockroach (d) Compound eye is called ocellus ***(UP-CPMT 2010)***

95. Mushroom gland is a part of :
(a) Male reproductive system of cockroach (b) Female reproductive system of cockroach
(c) Male reproductive system of rabbit (d) Female reproductive system of rabbit ***(UP-CPMT 2010)***

96. Which of the following is incorrect for *Pheretima*?
(a) Genital papillae are present on 17th and 19th segment
(b) Male genital pores are present on 18th segment
(c) Clitellum is present on segments 24, 25 and 26
(d) Segments of earthworm are called somites *(UP-CPMT 2010)*

97. Cold-blooded animals fall under the category of :
(a) Ectotherms (b) Psychrotherms (c) Endotherms (d) Thermophiles *(DUMET 2010)*

98. Phylum Mollusca can be distinguished from other invertebrates by the presence of :
(a) Bilateral symmetry and exoskeleton (b) A mantle and gills
(c) Shell and non-segmented body (d) A mantle and non-segmented body *(DUMET 2010)*

99. Air bladder is present in :
(a) Chondrichthyes (b) Star fishes (c) Actinopterygii (d) Flying fishes *(DUMET 2010)*

100. The basis of Protozoan classification is :
(a) Measurement (b) Shape (c) Locomotion (d) Number of nuclei *(MP-PMT 2010)*

101. In which phylum, the body is segmented :
(a) Porifera (b) Coelenterata (c) Annelida (d) Mollusca *(MP-PMT 2010)*

102. One of the following is not a characteristic feature of sponges :
(a) Cellular level of organisation (b) Presence of ostia (c) Intracellular digestion
(d) Body supported by chitin (e) Indirect development *(Kerala PMT 2010)*

103. Pseudocoelomate among these is :
(a) Porifera (b) Annelida (c) Aschelminthes (d) Mollusca (e) Platyhelminthes *(Kerala PMT 2010)*

104. Limbless amphibian is :
(a) *Ichthyophis* (b) *Hyla* (c) *Rana* (d) *Salamandra* (e) *Bufo* *(Kerala PMT 2010)*

105. Which one of the following is not a mammalian character?
(a) Presence of milk glands (b) Two pairs of limbs (c) Skin possessing hair
(d) Presence of external ears called pinnae (e) Homodont dentition *(Kerala PMT 2010)*

106. Flightless bird among the following is :
(a) *Columba* (b) *Neophron* (c) *Struthio* (d) *Corvus* (e) *Pavo* *(Kerala PMT 2010)*

107. Which one of the following animals possesses high regeneration capacity?
(a) *Planaria* (b) *Taenia* (c) *Salpa* (d) *Periplaneta* (e) *Ascidian* *(Kerala PMT 2010)*

108. "Organ of Jacobson" helps in :
(a) Touch (b) Vision (c) Smell (d) Hearing *(WB-JEE 2010)*

109. Cysticercus larva is formed in the life history of :
(a) *Taenia* (b) *Plasmodium* (c) *Leishmania* (d) *Wuchereria* *(WB-JEE 2010)*

110. Water vascular system is found in :
(a) Sea anemone (b) Sea pen (c) Sea cucumber (d) Sea horse *(WB-JEE 2010)*

111. Radula is found in :
(a) *Pila* sp. (b) *Chiton* sp. (c) *Lamellidens* sp. (d) *Pinctada* sp. *(WB-JEE 2010)*

112. Which one of the following is a catadromous fish?
(a) *Hilsa* sp. (b) *Mystus* sp. (c) *Anguilla* sp. (d) *Channa* sp. *(WB-JEE 2010)*

113. Which of the following is an exclusively echinoderm character?
(a) Radial symmetry (b) Tube feet
(c) Mesodermal endoskeleton (d) Coelom divided *(WB-JEE 2010)*

114. The phenomenon of torsion occurs in :
(a) Gastropoda (b) Pelecypoda (c) Cephalopoda (d) Amphineura *(AMU 2010)*

115. What will you look for to identify the sex of the following?
(a) Female *Ascaris* – Sharply curved posterior end (b) Male frog – A copulatory pad on the first digit of hind limb
(c) Female cockroach – Anal cerci (d) Male shark – Claspers borne on pelvic fins *(CBSE 2011)*

116. Which one of the following have the highest number of species in nature?
(a) Fungi (b) Insects (c) Birds (d) Angiosperms *(CBSE 2011)*

117. Which one of the following groups of animals is correctly matched with its one characteristic feature without even a single exception?
(a) Reptilia : Possess 3–chambered heart with one incompletely divided ventricle
(b) Chordates : Possess a mouth provided with an upper and a lower jaw
(c) Chondrichthyes : Possess cartilaginous endoskeleton
(d) Mammalia : Give birth to youngones *(CBSE 2011)*

118. Which one of the following animals is correctly matched with its particular name and taxonomic category?
(a) Tiger – *tigris*, the species (b) Cuttlefish – Mollusca, a class
(c) Human – Primata, the family (d) Housefly – *Musca*, an order *(CBSE 2011)*

119. In which one of the following the genus name, its two characters and its class/phylum are correctly matched?

	Genus name		Two characters	Class/Phylum
(a)	*Ascaris*	(*i*) (*ii*)	Body segmented Males and females distinct	Annelida
(b)	*Salamandra*	(*i*) (*ii*)	A tympanum represents ear Fertilization is external	Amphibia
(c)	*Pteropus*	(*i*) (*ii*)	Skin possesses hair Oviparous	Mammalia
(d)	*Aurelia*	(*i*) (*ii*)	Cnidoblasts Organ level of organisation	Coelenterata

(CBSE 2011)

120. Which of these statements are incorrect?
(*i*) Parapodia are lateral appendages in arthropods used for swimming
(*ii*) Radula in molluscs is the structure involved in excretion
(*iii*) Aschelminthes are dioecious
(*iv*) Echinoderm adults show radial symmetry
(*v*) Ctenophores are diploblastic
(a) (*i*) and (*ii*) (b) (*i*) and (*iii*) (c) (*i*), (*iv*) and (*v*)
(d) (*iii*) and (*v*) (e) (*ii*), (*iii*) and (*iv*) *(Kerala PMT 2011)*

121. Which of the following does not have an excretory system?
(a) *Myxine* (b) *Carcharodon* (c) *Balanoglossus*
(d) *Asterias* (e) *Catla* *(Kerala PMT 2011)*

122. Among the following which one is not a deuterostome?
(a) Sea urchin (b) Earthworm (c) Sand dollar (d) *Ichthyophis* *(J&K CET 2011)*

123. The most recently discovered animal phylum is :
(a) Concentricycloidea (b) Pognophora (c) Lorcifera (d) Ctenophora *(J&K CET 2011)*

124. Chondrichthyes is characterized by :
(a) Placoid scales (b) Ventral mouth
(c) Ctenoid scales and ventral mouth (d) Placoid scales and ventral mouth *(J&K CET 2011)*

125. In which of the following, the genus name, its two characters and its phylum are not correctly matched, whereas the remaining three are correct?

(a)	*Pila*	(*i*) (*ii*)	Body segmented Mouth with radula	Mollusca
(b)	*Asterias*	(*i*) (*ii*)	Spiny skinned Water vascular system	Echinodermata
(c)	*Sycon*	(*i*) (*ii*)	Pore bearing Canal system	Porifera
(d)	*Periplaneta*	(*i*) (*ii*)	Jointed appendages Chitinous exoskeleton	Arthropoda

(CBSE 2012)

126. One of the world's most poisonous fish toxins is released by:
(a) Clown fish (b) Sword fish (c) Eel fish (d) Puffer fish *(AIIMS 2012)*

127. Self-fertilization is seen in:
(a) *Ascaris* (b) *Pheretima* (c) Cockroach (d) *Fasciola* *(AFMC 2012)*

128. Organisms capable of maintaining constant body temperature are:
(a) Stenothermal (b) Homeothermal (c) Poikilothermal (d) Conformers *(AFMC 2012)*

129. Which of the following is a pseudocoelomate?
(a) Roundworm (b) Flatworm (c) Tapeworm (d) Hydatid worm *(BHU 2012)*

130. Mouth develops first in the embryo and anus is formed later in:
(a) Deuterostomes (b) Protostomes (c) Echinoderms (d) Chordates *(BHU 2012)*

131. Laurer's canal is found in:
(a) *Fasciola* (b) *Ascaris* (c) Sea anemone (d) Sea horse *(BHU 2012)*

132. The stages between larval moults in an insect are called:
(a) Pupae (b) Instars (c) Grubs (d) Caterpillars *(J&K-CET 2012)*

133. Which of the following belongs to class Gastropoda?
(a) Clam (b) Cuttle fish (c) Snail (d) Mussel *(J&K-CET 2012)*

134. Which of the following is not a characteristic feature of arthropods?
(a) Jointed appendages (b) Unsegmented body (c) Moulting (d) Articulated exoskeleton *(J&K CET 2012)*

135. The animals that rely on the heat from environment than metabolism to raise their body temperature are called:
(a) Ectothermic (b) Poikilothermic (c) Homeothermic (d) Endothermic *(AMU 2012)*

136. Which is the only phylum in kingdom Animalia without any nerve cell?
(a) Porifera (b) Coelenterata (c) Annelida (d) Nematoda *(AMU 2012)*

137. Consider the following statements with respect to characteristic feature of the kingdom:
(A) In Animalia, the mode of nutrition is autotrophic
(B) In Monera, the nuclear membrane is present
(C) In Protista, the cell type is prokaryotic
(D) In Plantae, the cell wall is present
Of the above statements:
(a) A alone is correct (b) B alone is correct (c) C alone is correct (d) D alone is correct (e) A, B and C are correct *(Kerala PMT 2012)*

138. Choose the correct pair:
(a) Radial symmetry—Coelenterates (b) Coelomates—Aschelminthes (c) Metamerism—Mollusca
(d) Triploblastic—Sponges (e) Metagenesis—Echinoderms *(Kerala PMT 2012)*

139. Which among these is not a homeotherm?
(a) *Aptenodytes* (b) *Testudo* (c) *Delphinus* (d) *Neophron* (e) *Ornithorhynchus* *(Kerala PMT 2012)*

140. Read the following statements and select the correct option:
(A) Circulatory system in arthropods is of closed type
(B) Parapodia in annelids help in swimming
(C) Phylum Mollusca is second largest phylum of Animalia
(D) Aschelminthes are dioecious
(a) A and C are wrong (b) A alone is wrong (c) C alone is wrong (d) C and D are wrong
(e) D alone is wrong *(Kerala PMT 2012)*

141. Match the name of the animal (column-I) with one characteristic (column-II) and the phylum/class (column-III) to which it belongs:

Column-I	Column-II	Column-III
(a) *Petromyzon*	Ectoparasite	Cyclostomata
(b) *Ichthyophis*	Terrestrial	Reptilia
(c) *Limulus*	Body covered by chitinous exoskeleton	Pisces
(d) *Adamsia*	Radially symmetrical	Porifera

(NEET 2013)

142. Which of the following are correctly matched with respect to their taxonomic classification?
(a) Flying fish, cuttle fish, silver fish—Pisces
(b) Centipede, millipede, spider, scorpion—Insecta
(c) Housefly, butterfly, tse tsefly, silverfish—Insecta
(d) Spiny ant eater, sea urchin, sea cucumber—Echinodermata *(NEET 2013)*

143. Which group of animals belong to the same phylum?
(a) Malarial parasite, *Amoeba*, Mosquito
(b) Earthworm, pinworm, tapeworm
(c) Prawn, scorpion, *Locusta*
(d) Sponge, sea anemone, starfish *(NEET 2013)*

144. One of the representatives of phylum Arthropoda is :
(a) Cuttle fish (b) Silver fish (c) Puffer fish (d) Flying fish *(NEET 2013)*

145. Which of the following animals lack alimentary canal (complete digestive system)?
(a) Earthworm (b) Jelly fish (c) Insect (d) Fishes *(AMU 2013)*

146. Name the character of phylum Aschelminthes which differentiates it from all other phyla of kingdom Animalia:
(a) Parasitic mode (b) Round in shape (c) Pseudocoelomate (d) Bilateral symmetry *(AMU 2013)*

147. Which of the following is an oviparous mammal?
(a) *Balaenoptera* (b) *Delphinus* (c) *Pteropus* (d) *Ornithorhynchus* *(AMU 2013)*

148. Torsion is the characteristic of :
(a) Gastropoda (b) Pelecypoda (c) Cephalopoda (d) Amphinura *(AMU 2013)*

149. *Planaria* possesses high capacity of:
(a) Alternation of generation (b) Bioluminescence
(c) Metamorphosis (d) Regeneration *(AIPMT 2014)*

150. A marine cartilaginous fish that can produce electric current is:
(a) *Trygon* (b) *Scoliodon* (c) *Pristis* (d) *Torpedo* *(AIPMT 2014)*

151. Select the Taxon mentioned that represents both marine and fresh-water species:
(a) Cephalochordata (b) Cnidaria (c) Echinodermata (d) Ctenophora *(AIPMT 2014)*

152. Which of the following characteristics is mainly responsible for diversification of insects on land ?
(a) Segmentation (b) Bilateral symmetry (c) Exoskeleton (d) Eyes *(AIPMT 2015)*

153. Which of the following endoprasites of humans does show viviparity?
(a) *Ancylostoma duodenale* (b) *Enterobius vermicularis*
(c) *Trichinella spiralis* (d) *Ascaris lumbricoides* *(AIPMT 2015)*

154. Which of the following represents the correct combination without any exception ?

	Characteristics	Class
(a)	Mammary glands, hair on body, pinnae, two pairs of limbs	Mammalia
(b)	Mouth ventral, gills without operculum, skin with placoid scales, persistent notochord	Chondrichthyes
(c)	Sucking and circular mouth, jaws absent, integument without scales , paired appendages	Cyclostomata
(d)	Body covered with feathers, skin moist and glandular, fore limbs form wings, lungs with air sacs	Aves

(AIPMT 2015)

155. Which of the following animals is not viviparous ? *(AIPMT 2015)*
(a) Flying fox (Bat) (b) Elephant (c) Platypus (d) Whale

156. A jawless fish, which lays eggs in fresh water and whose ammocoetes larvae after metamorphosis return to ocean is.
(a) *Eptatretus* (b) *Myxine* (c) *Neomyxine* (d) *Petromyzon* *(Re-AIPMT 2015)*

157. Chitinous exoskeleton of arthropods is formed by polymerisation of :
(a) Keratin sulphate and chondroitin sulphate (b) D- Glucosamine
(c) N-Acetyl glucosamine (d) Lipoglycans *(Re-AIPMT 2015)*

158. Metagenesis refers to :
(a) Presence of different morphic forms
(b) Alternation of generation between asexual and sexual phases
(c) Occurrence of drastic changes in form during post-embryonic development
(d) Presence of segmented body and parthenogenetic reproduction *(Re-AIPMT 2015)*

159. Body having meshwork of cells, internal cavities lined with food filtering flagellated cells and indirect development are characteristics of phylum.
(a) Porifera (b) Coelenterata (c) Mollusca (d) Protozoa *(Re-AIPMT 2014)*

160. Flame cells of flatworms help in :
(i) Osmoregulation (ii) Digestion (iii) Reproduction (iv) Excretion (v) Bioluminescence
(a) Only (ii) is correct (b) (i) and (iv) are correct (c) only (iii) is correct (d) (i) and (v) are correct
(e) (iv) and (v) are correct *(Kerala PMT 2015)*

161. Read the statements regarding echinoderms and choose correct option :
(i) All marine with organ system organization
(ii) Adults bilaterally symmetrical
(iii) They are dioecious
(iv) Fertilization is internal & indirect development
(v) Triploblastic and acoelomate animals
(a) (i) and (iii) are correct (b) (v) alone is correct
(c) (ii) and (v) are correct (d) (i) and (v) are correct
(e) (i) and (ii) are correct *(Kerala PMT 2015)*

162. Which class of animals includes all ectoparasites on some fishes :
(a) Amphibia (b) Osteichthyes
(c) Reptilia (d) Cyclostomata (e) Chondrichthyes
(Kerala PMT 2015)

163.

Organ	Phylum	Function
Parapodia	Annelida	? A
?, B	Ctenophora	Locomotion
?, C	Mollusca	Rasping organ
Malpighian tubules	Arthropoda	?, D
Cnidoblasts	Coelenterata	?, E

From the above table , find out the missing organ or function for A, B, C, D and E respectively.

(a) A– Swimming ,	B– Combplates,	C– Radula,	D– Excretion	E– Defence
(b) A– Defence,	B– Radula,	C– Combplates,	D–Excretion	E– Swimming
(c) A– Defence,	B– Radula,	C– Combplates,	D– Swimming	E– Excretion
(d) A– Protection,	B– Parapodia,	C– Visceral mass,	D– Locomotion,	E– Excretion
(e) A– Swimming,	B– Parapodia,	C– Combplates,	D– Anchorage,	E– Digestion

(Kerala PMT 2015)

164. Choose the correct statement:
(a) All pisces have gills covered by an operculum (b) All mammals are viviparous
(c) All cyclostomes do not have jaws and paired fins (d) All reptiles have a three - chambered heart
NEET (Phase-II) 2016

165. Which of the following features is not present in the Phylum-Arthropoda?
(a) Jointed appendages (b) Chitinous exoskeleton (c) Metameric segmentation (d) Parapodia
NEET (Phase-I) 2016

166. Which of the following characteristic features always holds true for corresponding group of animals?

(a)	3-chambered heart with one incompletely divided ventricle	Reptilia
(b)	Cartilaginous endoskeleton	Chondrichthyes
(c)	Viviparous	Mammalia
(d)	Possess a mouth with an upper and a lower jaw	Chordata

NEET (Phase-I) 2016

167. Which of the following features is not present in *Periplaneta americana*?
(a) Metamerically - segmented body
(b) Schizocoelom as body cavity
(c) Intermediate and radial cleavage during embryonic development
(d) Exoskeleton composed of N-Acetyl glucosamine *NEET (Phase-I) 2016*

168. Which is the National Aquatic Animal of India?
(a) Sea horse (b) Gangetic shark (c) River Dolphin (d) Blue whale *NEET (Phase-I) 2016*

169. Which one of the following characteristics in not shared by birds and mammals?
(a) Warm-blooded nature (b) Ossified endoskeleton (c) Breathing using lungs (d) Viviparity *NEET (Phase-I) 2016*

170. In case of poriferans, the spongocoel is lined with flagellated cells called?
(a) Ostia (b) Oscula (c) Choanocytes (d) Mesenchymal cells *(NEET 2017)*

171. Which among these is correct combination of aquatic mammals?
(a) Seals, dolphins, sharks (b) Dolphins, seals, *Trygon*
(c) Whales, dolphins, seals (d) *Trygon*, whales, seals *(NEET 2017)*

172. An important character that Hemichordates share with chordates is :
(a) Absence of notochord (b) Ventral tubular nerve cord
(c) Pharynx with gill slits (d) Pharynx without gill slits *(NEET 2017)*

173. Identify the vertebrate group of animals characterised by crop and gizzard in its digestive system:
(a) Amphibia (b) Aves (c) Reptilia (d) Osteichthyes *(NEET 2018)*

174. Which one of these animals is not a homeotherm?
(a) *Macropus* (b) *Camelus* (c) *Chelone* (d) *Psittacula* *(NEET 2018)*

175. Which of the following animals does not undergo metamorphosis?
(a) Earthworm (b) Moth (c) Tunicate (d) Starfish *(NEET 2018)*

ANSWERS

1. (c);	**2.** (b);	**3.** (c);	**4.** (c);	**5.** (c);	**6.** (b);	**7.** (c);	**8.** (d);	**9.** (c);	**10.** (d);
11. (c);	**12.** (b);	**13.** (d);	**14.** (c);	**15.** (b);	**16.** (a);	**17.** (a);	**18.** (b);	**19.** (a);	**20.** (e);
21. (c);	**22.** (e);	**23.** (c);	**24.** (b);	**25.** (d);	**26.** (a);	**27.** (b);	**28.** (c);	**29.** (b);	**30.** (d);
31. (a);	**32.** (a);	**33.** (b);	**34.** (a);	**35.** (b);	**36.** (a);	**37.** (d);	**38.** (d);	**39.** (b);	**40.** (b);
41. (c);	**42.** (b);	**43.** (d);	**44.** (d);	**45.** (e);	**46.** (a);	**47.** (d);	**48.** (a);	**49.** (b);	**50.** (a);
51. (b);	**52.** (a);	**53.** (d);	**54.** (c);	**55.** (d);	**56.** (d);	**57.** (c);	**58.** (a);	**59.** (a);	**60.** (a);
61. (b);	**62.** (c);	**63.** (c);	**64.** (b);	**65.** (c);	**66.** (c);	**67.** (c);	**68.** (c);	**69.** (d);	**70.** (c);
71. (c);	**72.** (a);	**73.** (b);	**74.** (b);	**75.** (b);	**76.** (b);	**77.** (b);	**78.** (b);	**79.** (c);	**80.** (d);
81. (b);	**82.** (b);	**83.** (d);	**84.** (c);	**85.** (c);	**86.** (b);	**87.** (a);	**88.** (d);	**89.** (a);	**90.** (c);
91. (e);	**92.** (a);	**93.** (b);	**94.** (a);	**95.** (a);	**96.** (c);	**97.** (a);	**98.** (d);	**99.** (c);	**100.** (c);
101. (c);	**102.** (d);	**103.** (c);	**104.** (a);	**105.** (e);	**106.** (c);	**107.** (a);	**108.** (c);	**109.** (a);	**110.** (c);
111. (a);	**112.** (c);	**113.** (b);	**114.** (a);	**115.** (d);	**116.** (b);	**117.** (c);	**118.** (a);	**119.** (b);	**120.** (a);
121. (d);	**122.** (b);	**123.** (c);	**124.** (d);	**125.** (a);	**126.** (d);	**127.** (d);	**128.** (b);	**129.** (a);	**130.** (b);
131. (a);	**132.** (b);	**133.** (c);	**134.** (b);	**135.** (a);	**136.** (a);	**137.** (d);	**138.** (a);	**139.** (b);	**140.** (b);
141. (a);	**142.** (c);	**143.** (c);	**144.** (b);	**145.** (b);	**146.** (c);	**147.** (d);	**148.** (a);	**149.** (d);	**150.** (d);
151. (d);	**152.** (c);	**153.** (c);	**154.** (b);	**155.** (c);	**156.** (d);	**157.** (c);	**158.** (b);	**159.** (a);	**160.** (b);
161. (a);	**162.** (d);	**163.** (a);	**164.** (c);	**165.** (d);	**166.** (b);	**167.** (c);	**168.** (c);	**169.** (d);	**170.** (c);
171. (c);	**172.** (c);	**173.** (b);	**174.** (c);	**175.** (a).					

HINTS OF SOME DIFFICULT MULTIPLE CHOICE QUESTIONS

4. (c) : All these animals belong to phylum Arthropoda characterized by jointed legs.

21. (c) : Because in all the vertebrates, notochord is replaced by vertebral column so notochord is not present in adult stage.

39. (b) : Presence of biradial symmetry and absence of cnidoblasts are peculiar features of phylum Ctenophora to which *Ctenoplana* and *Beroe* belong.

55. (d) : Air bladder is peculiar feature of bony fishes while sharks belong to cartilage fishes (class Chondrichthyes).

84. (c) : Larva of echinoderms has bilateral symmetry (primary) but adult has pentamerous radial symmetry which is called secondary symmetry.

104. (a) : Subclass Apoda of class Amphibia includes limbless amphibians. It includes caecilians e.g. *Ichthyophis*.

131. (a) : Laurer's canal is a small tubular canal found in female reproductive system of flukes (e.g. *Fasciola*– Liver fluke) and receives the penis and sperms from another fluke during copulation.

157. (c) : Exoskeleton of arthropods is formed of plates, called **sclerites**, which are formed of **chitin** which is a polymer of N-Acetyl glucosamine.

165. (d) : Parapodia are unjointed foliaceous appendages of polychaete annelids e.g. *Nereis*.

B. CBSE - PMT (MAIN EXAMINATION) QUESTIONS :

1. Differentiate the following on the basis of characters asked in the subparts :

(a) Human/Bird (number of condyles)

(b) Whale and shark (number of respiratory apparatus and position)

(c) Sea anemone/Ctenophora (symmetry)

(d) Crocodile/Toad (number of chambers of heart)

(e) Moth/Butterfly (wings in sitting position). ***(CBSE 2006)***

Ans. **(a)** Human – Dicondylic; Birds – Monocondylic.

(b) Whale – Lungs (one pair) – on the sides of heart; Shark – 5 pairs of gill clefts (external), pharyngeal gills – ten (5 pairs).

(c) Sea anemone – Radial; Ctenophora – Biradial.

(d) Crocodile – complete 4 chambers; Toad – 3 chambers.

(e) Moth = Horizontal; Butterflies = Vertically upward.

2. Whale, Peacock, Bat, Earthworm, Starfish, House lizard, Scorpion, Lizard.

In the above animals :

(i) Which one is different in symmetry and what is its symmetry?

(ii) Which animal belongs to same class and phylum?

(iii) Which animals have three ear ossicles? Give sequence of sound conduction in them.

(iv) Which animals belong to same phylum?

(v) Which two animals are poisonous? Give their class and phylum. ***(CBSE 2007)***

Ans. **(i)** Starfish adult has pentamerous radial symmetry while rest are billaterally symmetrical.

(ii) Whale and bat belong to class Mammalia and phylum Chordata.

(iii) Whale and bat have three ear ossicles. The sequence of sound wave conduction is Malleus→Incus→Stapes.

(iv) Whale, bat, House lizard, Peacock belong to phylum Chordata. Honey bee and Scorpion belong to phylum Arthropoda.

(v) Lizard (Phylum – Chordata, Class – Reptilia)
Scorpion (Phylum – Arthropoda, Class-Arachnida).

3. Differentiate Ctenophora and Echinodermata according to their body organisation and body symmetry. ***(CBSE 2008)***

Ans.

Characters	Ctenophora	Echinodermata
1. Body organisation	Diploblastic and tissue organisation	Triploblastic and organ-system organisation.
2. Body symmetry	Biradial symmetry	Adult with pentamerous radial symmetry while larva has bilateral symmetry.

4. (i) Match the contents of Column I with those of Column II :

Column I	Column II
(a) Erythropoietin	**(i)** Collateral glands
(b) Smooth muscle fibres	**(ii)** Typhlosole
(c) Cockroach	**(iii)** Involuntary
(d) Petromyzon	**(iv)** Gizzard
	(v) Hormone
	(vi) Radula
	(vii) Juxtaglomerular cells
	(viii) Circular mouth
	(ix) Fusiform
	(x) Wall of blood vessels
	(xi) Choanocytes

(ii) For Column-I, in Column-II some terms are not matching. Write the name of anyone with its phylum. ***(CBSE 2009)***

Ans. **(i)** **(a)** – (v), (vii); **(b)** – (iii), (ix), (x); **(c)** – (i), (iv); **(d)** – (viii).

(ii) Typhlosole = Phylum Annelida

Radula = Phylum Mollusca

Choanocytes = Phylum Porifera

5. Match the columns and answer the questions given below :

Column I	Column II	Column III
A. *Nereis*, Earthworm, Cockroach, Leech	**(1)** Bony endoskeleton, vivipary	**(i)** Phylum
B. Shark, Whale, Dolphin, Bat nervous system	**(2)** Radial symmetry, dorsal hollow	**(ii)** Chambers of heart
C. Ostrich, Lizard, Peacock, Duckbilled platypus	**(3)** Bilateral, metamerism	**(iii)** Nourishment of young ones
D. Starfish, Sea anemone, Sea cucumber, Sea urchin	**(4)** Homeothermy, oviparous	**(iv)** Level of organization

(a) Which characters of column-II are common among the animals of column-I?

(b) Which characters of column-III are mismatched with column-I and how these characters are mismatched?

(*CBSE 2009*)

Ans. (a) **A –** (3); **B –** (1); **C –** (4); **D –** (2)

(b) **(i)** Cockroach belongs to phylum Arthropoda, while others belong to phylum Annelida.

(ii) Shark has 2-chambered heart, while others have 4- chambered heart.

(iii) Duckbilled platypus nourishes the young on milk of mammary glands.

(iv) Sea anemone has tissue organisation, while others have organ-system organisation.

6. Which one of the following statements is totally wrong about the occurrence of notochord while the other three are correct?

(a) It is absent throughout life in humans from the very beginning.

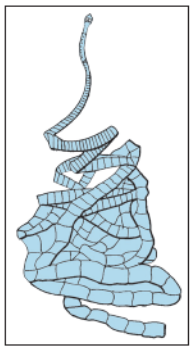
(b) It is present throughout life in *Amphioxus*.

(c) It is present only in larval tail in Ascidians.

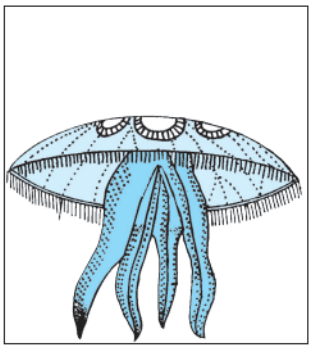
(d) It is replaced by vertebral column in adult frog. **(*CBSE 2011*)**

Ans. (a) Notochord is present in the embryo of humans.

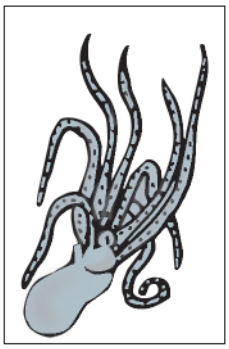
7. The figure shows four animals (A), (B), (C) and (D). Select the correct answer with respect to a common characteristics of two of these animals.



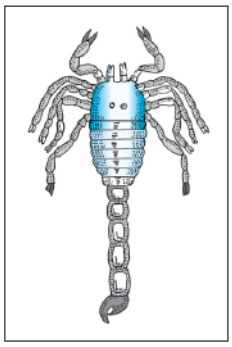
(A)



(B)



(C)



(D)

(a) (A) and (B) have cnidoblasts for self defence.

(b) (C) and (B) have true coelom.

(c) (A) and (D) respire mainly through body wall.

(d) (B) and (C) show radial symmetry. **(*CBSE 2011*)**

Ans. (b).

8. Which one of the following pairs of animals are similar to each other pertaining to the feature stated against them?

(a) *Pteropus* and *Ornithorhynchus*—Viviparity.

(b) Garden lizard and crocodile—Three chambered heart.

(c) *Ascaris* and *Ancylostoma*—Metameric segmentation.

(d) Sea horse and flying fish—Cold blooded (Poikilothermal). **(*CBSE 2012*)**

Ans. (d).

9. Which one of the following categories of animals, is correctly described with no single exception in it?

(a) All reptiles possess scales, have a three-chambered heart and cold blooded.

(b) All bony fishes have four pairs of gills and an operculum on each side.

(c) All sponges are marine and have collar cells.

(d) All mammals are viviparous and possess diaphragm for breathing. *(CBSE 2012)*

Ans. (b)

10. Which one of the following organisms is scientifically correctly named, correctly printed according to the International Rules of Nomenclature and correctly described?

(a) *Musca domestica*—the common house lizard, a reptile.

(b) *Plasmodium falciparum*—A protozoan pathogen causing most serious type of **malaria.**

(c) *Felis tigris*—the Indian tiger, well protected in Gir forests.

(d) *E. coli*—Full name *Entamoeba coli*, a common occurring bacterium in human intestine. *(CBSE 2012)*

Ans. (b)

11. Which one of the following option gives the correct categorization of six animals according to nitrogenous waste they give out?

	Ammonotelic	Ureotelic	Uricotelic
(a)	Pigeon, humans	Aquatic amphibia, lizards	Cockroach, frog.
(b)	Frog, lizards	Aquatic amphibia, humans	Cockroach, pigeon.
(c)	Aquatic amphibia	Frog, humans	Pigeon, lizard, cockroach.
(d)	Aquatic amphibia	Cockroach, humans	Frog, pigeon, lizard. *(CBSE 2012)*

Ans. (c).

C. MATCHING TYPE QUESTIONS :

1.Match the terms in column A with suitable terms in column B :

Column A	Column B
(i) Claspers	(a) Coelenterates
(ii) True salivary glands	(b) Birds and mammals
(iii) Cnidoblasts	(c) Nematodes
(iv) Paragastric cavity	(d) Birds
(v) Endothermic	(e) Chondrichthyes
(vi) Pouched mammals	(f) Annelids
(vii) Caecilians	(g) Mammals
(viii) Pseudocoel	(h) Amphibians
(ix) Nephridia	(i) Metatherians
(x) Pneumatic bones	(j) Sponges

2. Match the terms in column I with suitable terms in column II and select the correct answer :

Column I	Column II
A. Protozoa	1. *Pennatula*
B. Aschelminthes	2. *Bereo*
C. Porifera	3. *Monocystis*
D. Ctenophora	4. *Wuchereria*
E. Cnidaria	5. *Cliona*

(a) A-3, B-5, C-4, D-1, E-2 (b) A-4, B-3, C-5, D-2, E-1 (c) A-3, B-4, C-5, D-2, E-1

(d) A-2, B-4, C-5, D-3, E-1 (e) A-3, B-4, C-5, D-1, E-2 *(Kerala-PMT 2008)*

3. Match the following and select the correct answer :

Column I	Column II
A. Choanocytes	1. Platyhelminthes
B. Cnidoblasts	2. Ctenophora
C. Flame cells	3. Porifera
D. Nephridia	4. Coelenterata
E. Comb plates	5. Annelida

(a) A-2, B-1, C-4, D-5, E-3 (b) A-2, B-4, C-1, D-5, E-3 (c) A-5, B-1, C-3, D-2, E-4
(d) A-3, B-4, C-1, D-5, E-2 (e) A-3, B-1, C-4, D-5, E-2 *(Kerala-PMT 2010)*

4. Match the following and select the correct option :

Column I	Column II
A. Cyclostomes	1. Hemichordata
B. Aves	2. Urochordata
C. Tunicates	3. Agnatha
D. *Balanoglossus*	4. Pisces
E. Osteichthyes	5. Tetrapod

(a) A-1, B-2, C-3, D-4, E-5 (b) A-2, B-3, C-4, D-1, E-5 (c) A-3, B-5, C-2, D-1, E-4
(d) A-3, B-1, C-5, D-2, E-4 (e) A-5, B-3, C-2, D-1, E-4 *(Kerala-PMT 2011)*

5. Match the following and select the correct option :

A. *Physalia*	1. Sea anemone
B. *Meanderina*	2. Brain coral
C. *Gorgonia*	3. Sea fan
D. *Adamsia*	4. Portuguese man-of-war

(a) A-3, B-2, C-1, D-4 (b) A-4, B-3, C-3, D-1 (c) A-4, B-2, C-3, D-1
(d) A-2, B-3, C-1, D-4 (e) A-1, B-2, C-3, D-4 *(Kerala-PMT 2012)*

ANSWERS

1. *(i)* (e); *(ii)* (g); *(iii)* (a); *(iv)* (j); *(v)* (b); *(vi)* (i); *(vii)* (h); *(viii)* (c); *(ix)* (f); *(x)* (d).
2. (c); **3.** *(d)*; **4.** (c); **5.** *(c)*.

D. ASSERTION TYPE QUESTIONS :

The following questions consist of two statements each, printed as *Assertion* and *Reason*. While answering these questions, you are required to choose any one of the following four responses :

A. If both *Assertion* and *Reason* are true and *Reason* is correct explaination of *Assertion*.
B. If both *Assertion* and *Reason* are true but *Reason* is not correct explaination of *Assertion*.
C. If *Assertion* is true but *Reason* is false.
D. If both *Assertion* and *Reason* are false.

1. Assertion : Metamorphosis in frog is said to be progressive.
Reason : Metamorphosis in frog is controlled by thyroxine hormone.
A B C D

2. Assertion : Lung fishes (*e.g. Protopterus*) act as connecting link between fishes and amphibians.
Reason : These have characters of both fishes and amphibians.
A B C D

3. Assertion : Amphibians have thin, moist, glandular and vascular skin.
Reason : Amphibians respire through their skin.
A B C D

4. Assertion : Birds have pneumatic bones.
Reason : Birds reduce their body weight for normal flight.
A B C D

5. Assertion : Camels are commonly called **ship of desert.**
Reason : Camels have large number of water cells in their stomach to store the water for emergency functions.
A B C D

6. Assertion : Silver fish shows complete metamorphosis.
Reason : In the life history of silver fish, there are four stages : Egg→Larva→Pupa→Adult
A B C D

7. **Assertion :** Cold blooded animals do not have fat layer.
Reason : They use their fat in metabolism during hibernation.
A **B** **C** **D** (*AIIMS 1997*)

8. **Assertion :** Bats and whales are classified as mammals.
Reason : Bats and whales have four – chambered heart.
A **B** **C** **D** (*AIIMS 2003*)

9. **Assertion :** All birds except the ones like Koel (cuckoo) build nests for retiring and taking rest during night (day time for nocturnal birds).
Reason : Koel lays the eggs in the nest of tailor bird.
A **B** **C** **D** (*AIIMS 2003*)

10. **Assertion :** Tapeworms, roundworms and pinworms are endoparasites of human intestine.
Reason : Improperly cooked food is the source of all intestinal infections.
A **B** **C** **D** (*AIIMS 2004*)

11. **Assertion :** The honey bee queen copulates only once in her life time.
Reason : The honey bee queen can lay fertilized as well as unfertilized eggs.
A **B** **C** **D** (*AIIMS 2004*)

12. **Assertion :** The duck-billed platypus and spiny ant-eater, both are egg-laying animals yet they are grouped under mammals.
Reason : Both of them have seven cervical vertebrae and 12 pairs of cranial nerves.
A **B** **C** **D** (*AIIMS 2005*)

13. **Assertion :** *Euglena* is a plant due to presence of chlorophyll.
Reason : *Euglena* cannot be classified on the basis of two kingdom system.
A **B** **C** **D** (*AIIMS 2007*)

14. **Assertion :** Bats and whales are classified as mammals.
Reason : Bats and whales have four-chambered heart.
A **B** **C** **D** (*AIIMS 2008*)

15. **Assertion :** The honey bee queen copulates only once in life.
Reason : It can lay both fertilized and unfertilized eggs.
A **B** **C** **D** (*AIIMS 2009*)

ANSWERS

1. B;	**2.** A;	**3.** A;	**4.** A;	**5.** C;	**6.** D;	**7.** A;.	**8.** B;	**9.** D;	**10.** C;
11. B;	**12.** A;	**13.** B;	**14.** B;	**15.** B.					

E. ADDITIONAL MULTIPLE CHOICE QUESTIONS :

Choose the correct answer :

1. Which one of the following is not a living fossil?
(a) King crab (b) *Sphenodon* (c) *Archaeopteryx* (d) *Peripatus*

2. Animal migration does not occur in the case of :
(a) Salmon (b) Siberian crane (c) Salamander (d) Arctic tern

3. Which one of following is a matching set of a phylum and its three examples?
(a) Cnidaria – *Bonellia, Physalia, Aurelia* (b) Platyhelminthes – *Planaria, Schistosoma, Enterobius*
(c) Mollusca – *Loligo, Teredo, Octopus* (d) Porifera – *Spongilla, Euplectella, Pennatula*

4. Metameric segmentation is the characteristic of :
(a) Platyhelminthes and Arthropoda (b) Echinodermata and Annelida
(c) Annelida and Arthropoda (d) Mollusca and Chordata

5. Biradial symmetry and lack of cnidoblasts are the characteristics of :
(a) Starfish and sea anemone (b) *Ctenoplana* and *Bereo*
(c) *Aurelia* and *Paramecium* (d) *Hydra* and Starfish

6. In which one of the following sets of animals do all the four give birth to young ones?
(a) Lion, Bat, Whale, Ostrich (b) Platypus, Penguin, Bat, Hippopotamus
(c) Shrew, Bat Cat, Kiwi (d) Kangaroo, Hedgehog, Dolphin, Loris

7. Which one of the following has an open circulatory system?
(a) *Hirudinaria* (b) *Octopus* (c) *Pheretima* (d) *Periplaneta*

8. In molluscs, the eye is present over a stalk called :
(a) Ostracum (b) Operculum (c) Ommatophores (d) Osphradium

9. All mammals without any exception are characterized by :
(a) Viviparity and biconcave red blood cells (b) Extra-abdominal testes and 4-chambered heart
(c) Heterodont teeth and 12 pairs of cranial nerves (d) A muscular diaphragm and milk producing glands

10. Commercial pearl is formed by :
(a) Oyster (b) Octopus (c) Lamellidens (d) None of these

11. Which is incorrect?
(a) Oligochaeta – *Pheretima* (b) Hirudinea – *Hirudo* (c) Nematoda – *Ascaris* (d) Polychaeta – *Lumbricus*

12. Which of the following classes exhibits polymorphism?
(a) Hydrozoa (b) Scyphozoa (c) Calcaria (d) Polychaeta

13. Illicium is modification of :
(a) Dorsal fin (b) Caudal fin (c) Scales (d) Ist dorsal spine

14. A poisonous lizard is :
(a) *Varanus* (b) *Chamaeleon* (c) *Ancistrodon* (d) *Heloderma*

15. Pseudocoelom occurs in :
(a) *Ascaris* (b) *Taenia solium* (c) *Fasciola hepatica* (d) *Planaria*

16. Which of the following statements is true?
(a) All living members of class Cyclostomata are parasites of some fishes
(b) There are about 2000 species in the class Osteichthyes
(c) *Cliona* belongs to the subphylum Cephalochordata
(d) Arthropods are diploblastic animals
(e) *Ascaris lumbricoides* is a flat worm

17. The internal buds of fresh-water sponges are otherwise called :
(a) Choanocyte (b) Gemmule (c) Osculum (d) Blastula (e) Gastrula

18. Which of the following statements is / are not true?
1. In Urochordata, notochord is present only in larval tail
2. In Cephalochordata, notochord extends from head to tail region
3. *Branchiostoma* belongs to Hemichordata
4. Only one class of living members, class Cyclostomata represents the agnathans
(a) 1, 2 and 4 only (b) 3, 4 and 1 only (c) 3 only
(d) 1 and 4 only (e) 3 and 4 only

19. Which of the following statements are true / false?
1. In *Torpedo*, the electric organs are capable of generating strong electric current to paralyze prey
2. Bony fishes use pectoral, pelvic, dorsal, anal and caudal fins in swimming
3. Amphibian skin is moist and has thick scales
4. Birds are poikilothermic animals
5. Most unique mammalian characteristic is the presence of milk-producing mammary glands

(a) 1, 2 and 3 are true; 4 and 5 are false
(b) 1, 2 and 5 are true; 3 and 4 are false
(c) 1, 4 and 5 are true; 2 and 3 are false
(d) 1, 2 and 4 are true; 3 and 5 are false
(e) Only 4 is true; 1, 2, 3 and 5 are false.

20. Which of the following pairs are correctly matched?

Animals	Morphological features
(1) Crocodile	4-chambered heart
(2) Sea urchin	Parapodia
(3) *Obelia*	Metagenesis
(4) Lemur	Thecodont

(a) Only 1 and 2 (b) 1, 3 and 4 (c) 2, 3 and 4 (d) Only 1 and 4

21. Reason of death of a patient due to cobra-bite is :
(a) Destruction of RBCs (b) Inactivation of nerves
(c) Permanent contraction of muscles (d) None of the above

22. Exoskeleton/scales are absent in :
(a) Fish (b) Reptiles (c) *Ichthyophis* (d) *Rana tigrina*

23. Gill cover is absent in :
(a) Shark (b) *Labeo* (c) Salmon (d) All of these

24. The class of Coelenterata which shows polymorphism is :
(a) Hydrozoa (b) Scyphozoa (c) Anthozoa (d) All of these

25. The cyst wall of *Euglena* is formed of :
(a) Lipids (b) Histones (c) Carbohydrates (d) Lipoproteins

26. Types of quill (flight) feathers are :
(a) Down feathers (b) Coverts (c) Filoplumes (d) Remiges

27. Which of the following is true about preen gland?
(1) Occur in birds (2) Also known as uropygial gland
(3) Occur in bats (4) Help in digestion
(a) 1, 2 and 3 are correct (b) 1 and 2 are correct (c) 2 and 4 are correct (d) 1 and 3 are correct

28. Cartilaginous fish have :
(1) Placoid scales (2) Cycloid or ctenoid scales (3) Scroll valve (4) Operculum
(a) 1, 2 and 3 are correct (b) 1 and 2 are correct (c) 2 and 4 are correct (d) 1 and 3 are correct

29. Which of the following belongs to phylum Arthropoda?
(1) Cockroach (2) Gold fish (3) Silver fish (4) Cuttle fish
(a) 1, 2 and 3 are correct (b) 1 and 2 are correct (c) 2 and 4 are correct (d) 1 and 3 are correct

30. Which of the following is absent in fore limb of frog?
(1) Brachium (2) Webs (3) Antebrachium (4) Tarsals
(a) 1, 2 and 3 are correct (b) 1 and 2 are correct (c) 2 and 4 are correct (d) 1 and 3 are correct

ANSWERS

1. (c);	**2.** (c);	**3.** (c);	**4.** (c);	**5.** (b);	**6.** (d);	**7.** (d);	**8.** (c);	**9.** (d);	**10.** (a);
11. (d);	**12.** (a);	**13.** (d);	**14.** (d);	**15.** (a);	**16.** (a);	**17.** (b);	**18.** (c);	**19.** (b);	**20.** (b);
21. (b);	**22.** (d);	**23.** (a);	**24.** (a);	**25.** (c);	**26.** (d);	**27.** (b);	**28.** (d);	**29.** (d);	**30.** (c).

Chapter Practice Test

Time Allowed : 1 : 30 Hours *Maximum Marks : 35*

1. Which type of organization is found in coelenterates ? (1)
2. What is metameric segmentation ? In which group of animals it is found ? (1)
3. Which conditions increase the survival chances of youngs of mammals ? (1)
4. Give the cause of succesfulness of arthropods. (1)
5. Define retrogressive metamorphosis ? In which animal it is found ? (1)
6. Enlist four peculiar characters of Porifera. Name two examples. (2)
7. Differentiate flat worms and round worms. (4 characters). (2)
8. What is haemocoel ? Animals of which two phyla have haemocoel ? (2)
9. To which group of animals *Petromyzon* belongs ? Enlist three peculiar features of this group. (2)
10. To Which group of animals duck billed platypus belongs ? Give its evolutionary significance. (2)
11. Enlist six peculiar characters of class Aves. State three examples. (3)
12. Write a note on coelom in various groups of animals. (3)
13. Enlist excretory organs of various groups of invertebrates. (3)
14. Discuss four peculiar characters found in all the chordates. (3)
15. Enlist six peculiar characters of phylum Mollusca. Name three examples. (3)
16. Give reasons for the following : (5)
    (i) Mammals are most adapted vertebrates.
    (ii) Birds can fly but the mammals cannot.
    (iii) All the chordates are not vertebrates.

❑❑❑

To check your performance, see ANSWERS TO CHAPTER PRACTICE TEST at the end of Part I of the book.

UNIT II

STRUCTURAL ORGANISATION IN ANIMALS AND PLANTS

- MORPHOLOGY OF FLOWERING PLANTS
- ANATOMY OF FLOWERING PLANTS
- STRUCTURAL ORGANISATION IN ANIMALS

CHAPTER 5

MORPHOLOGY OF FLOWERING PLANTS

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MORPHOLOGY

Every living organism has a fixed form and it is because of this reason that we are able to distinguish most of them just due to their external structure. The study of external structures of organs is known as **external morphology** and that of internal structures as **internal morphology** or **anatomy.** Study of external morphology or external appearance of higher plants is necessary in order to describe the plants in an accurate fashion. This study further enables us to distinguish between almost similar looking plants. So, the plants are identified by their morphological characters. Variation in plants is found not only in external forms but also in their anatomical characters which are represented by different types of tissue systems. The flowering plants (angiosperms) are most diverse and wide-spread of all plant groups. There are about 3,00,000 species of flowering plants on the earth. Morphology along with anatomy constitutes the base of studying pattern of life forms.

There are very minute plants like *Wolffia* (smallest angiosperm) and tallest like *Eucalyptus*. Depending upon their habitat they can be classified as hydrophytes, mesophytes and xerophytes.

PARTS OF FLOWERING PLANT

Various parts of an angiospermic plant can be studied from a small plant with intact roots as *Solanum nigrum* (Mako), *Petunia*, *Brassica campestris* (Mustard) etc. These parts are **roots, stems, leaves, flowers, fruits** and **seeds** (Fig. 1). Parts of a plant mainly concerned with the nutrition and growth are called vegetative parts *e.g.* root, stem and leaf. The reproductive part is flower which is essentially concerned with the sexual reproduction of a plant. A typical angiospermic plant can be divided into two main parts :

I. Root system

II. Shoot system

I. Root system

The root and its branches together constitute the root system. The root system is typically underground and consists of main root and its branches. The root formed directly from the radicle is called **Tap root.** The tap root along with its branches forms the **tap root system**. There is a main thick root, called as **Primary root,** main root or tap root. It bears many lateral branches or **Secondary**

roots. The branches of secondary roots are called as **Tertiary roots**. The fine endings of the branches of a root are called as **rootlets.** Root is the underground (positively geotropic), non-green part of the plant. The major functions of the root are :

1. To fix the plant in the soil.

2. To absorb water and mineral salts.

3. To hold the soil particles.

II. Shoot system

It constitutes the aerial, epiterranean parts of a plant lying above the soil. The main axis with its branches, leaves, flowers and fruits is collectively called shoot system. The axis of the shoot is called as **stem.** The branches bear flat, green, expanded lateral out-growths called as **leaves**. They are borne on special points known as **nodes**. The distance between two adjacent nodes is known as **internode**. The upper angle formed between the leaf and the stem is called **axil.** A lateral bud which develops in the axil of a leaf is known as **axillary bud**. This bud later on bears a branch. The stem along with its branches and leaves forms the **shoot.** It is positively phototropic and negatively geotropic. At the tip of stem branches lie the terminal or **apical bud.** It is responsible for increasing the length of the stem.

The chief **functions** of stem are :

1. To hold the leaves, flowers and fruits.

2. To expose the leaves to sunlight.

3. To expose the fruits and seeds for proper dispersal.

4. To conduct the water and minerals from roots to leaves.

5. To transport the food from leaves to all parts of plant such as roots, flowers, fruits etc.

Leaves. A leaf is a dissimilar, green, flat, expanded lateral outgrowth of stem or its branches on a node. Each leaf consists of three parts *i.e.* **leaf base** or **vagina, petiole** and **lamina.** Leaf base is the lowermost part of the leaf by which it is attached with the node of stem. Petiole is the stalk of leaf. The leaf blade or lamina is the expanded green part which is supported by veins. The major **functions** of the leaves are :

(1) Photosynthesis (2) Gaseous exchange (3) Transpiration.

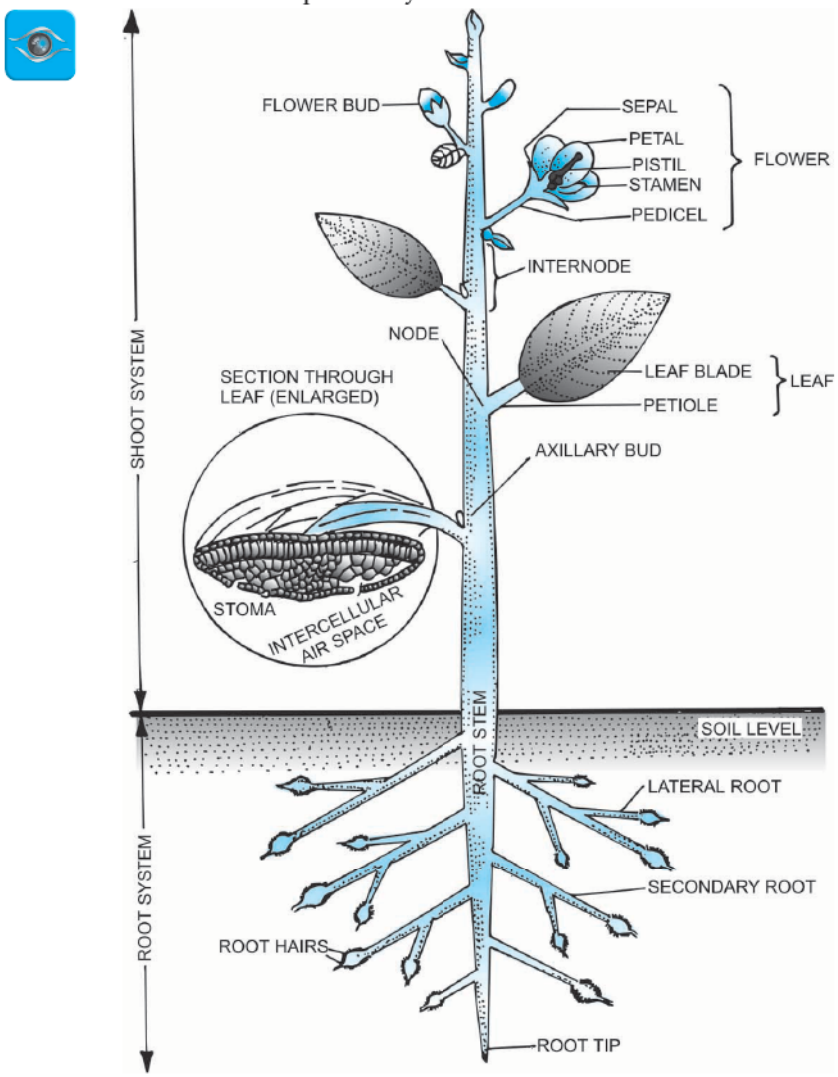


Fig. 1. The parts of flowering plant (Entire plant body).

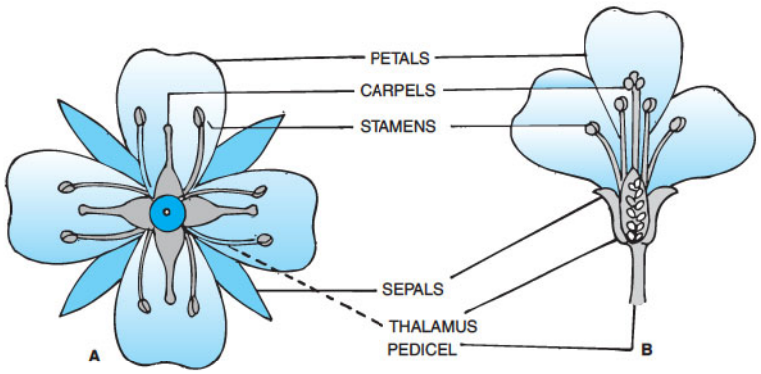


Fig. 2. Parts of a flower : **A.** Surface view; **B.** L.S.

Flower. It is a modified branch which is usually brightly coloured. The stalk of flower is called **pedicel** (Fig. 2). Swollen flat tip of pedicel forms the **thalamus** or **receptacle.** The four types of floral leaves—sepals, petals, stamens and carpels appear from thalamus. **Stamens** (androecium) and **carpels** (gynaecium) constitute the essential parts of a flower. Non-essential parts are **sepals** (calyx) and **petals** (corolla). The sepals are usually green and petals are coloured and showy. Each stamen consists of a stalk like **filament** and flattened globoid top called **anther.** The anthers produce the **pollen grains.** Carpel shows basal swollen ovary, middle elongated style and upper terminal stigma. The ovary contains ovules. The **functions** of a flower are:

1. It is the part of a plant which helps in sexual reproduction.

2. It bears male sex organs *i.e.* stamens and female sex organs *i.e.* carpels.

3. Ovary after fertilization ripens into fruit which contains seeds and thus is responsible for continuation of the race.

Fruits and seeds. The fruit is a ripened ovary mostly developed after fertilization. The fruit encloses and protects the seeds. Seed is the ripened ovule. It contains an embryo and reserve food for developing the embryo. Outer protective covering is called as testa or seed coat. Embryo axis is a bipolar elongated structure with which food laden cotyledons are attached. The two ends can be distinguished as **plumule** and **radicle.** The plumule is the future shoot and radicle is the future root. The seed under suitable conditions germinates to give rise to young plant called seedling.

ROOT

Root is an underground cylindrical part of the plant which develops from radicle and grows vertically down into the soil. Root lacks leaves, nodes, internodes and buds. Root and its branches constitute **root system**.

Characteristics of root

1. They normally constitute the descending part of the plant axis.

2. Root develops from radicle.

3. Roots are cylindrical structures.

4. Root is positively geotropic.

5. Buds and leaves are usually absent.

6. Root is colourless due to the absence of chlorophyll.

7. Root cap is present over the apex.

8. The branches of root arise from inner region, thus are endogenous.

9. Root possesses root hairs which are always unicellular.

The primary functions of the root is to fix the plant firmly with the soil and to absorb water and mineral nutrients. In submerged hydrophytes and floating aquatics.(*e.g. Ceratophyllum, Myriophyllum, Utricularia, Hydrilla*), these functions are not critical. In these plants root system is either poorly developed or totally absent.

REGIONS OF TYPICAL ROOT

The following parts can be distinguished in a typical root :

1. Root cap. Root cap is thickened, protective cap like structures present at the tip of root apex (Fig. 3). Without it, the tender root would be unable to penetrate the hard soil. It protects the young growing apex of roots in all the terrestrial plants. The cells of root cap secrete mucilage which lubricates the passage of root through the soil. When root pushes deeper into the soil particles, its outer cells are continuously peeled off and replaced by new cells formed from root meristem.

2. Meristematic zone or **Zone of cell division**. It is a small region present behind root cap (sub-terminal). It is about 1 mm long. It represents the growing point. Cells are thin, have large nucleus and are non-vacuolated. It is made up of actively dividing meristematic cells. This region adds new cells and is responsible for longitudinal growth of the root. It also absorbs mineral salts.

3. Zone of elongation. It lies just above the meristematic zone and is about 5 mm. long. The cells of this zone do not divide. These cells elongate rapidly. These also possess the power of absorption of water and mineral salts from the soil. In cells of this zone, small vacuoles develop and later the vacuoles fuse to form one large central vacuole filled with cell sap.

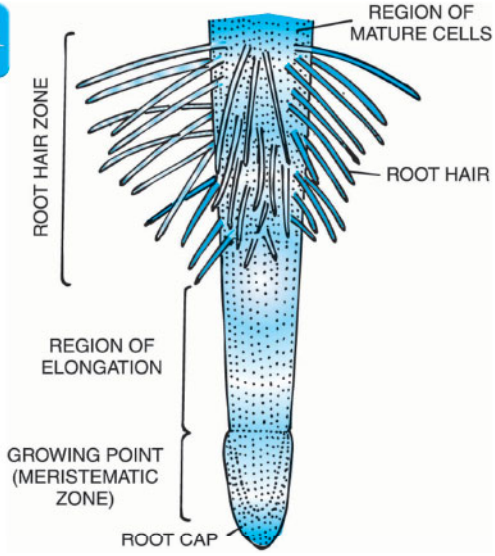


Fig. 3. The regions of root tip.

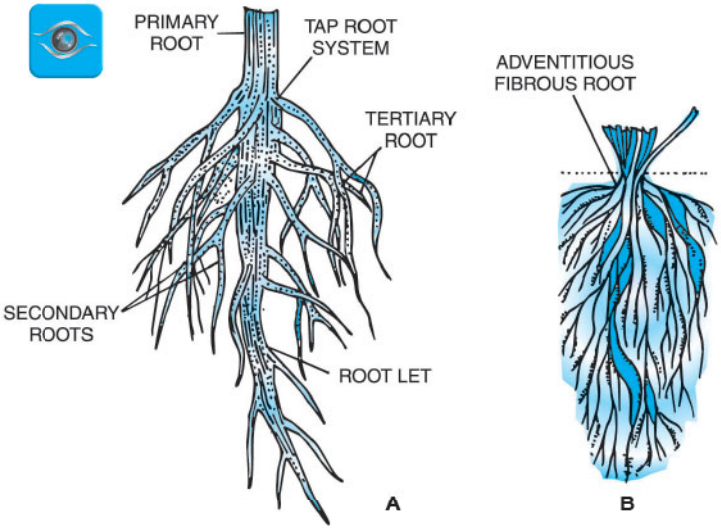


Fig. 4. Kinds of roots. **A.** Tap root; **B.** Adventitious fibrous root.

4. Root hair zone. Root hair zone is 1–6 cm in length. Root hairs appear from outer cells of this zone in the form of tubular outgrowths. Most of the water absorption takes place through this zone. When the cells of root hair zone mature root hairs shrivel and become non-functional. New root hairs appear in the older parts of zone of elongation.

5. Zone of cell maturation (differentiation). It is called as root hair maturation zone. Large number of unicellular root hairs are present which mainly absorb water and minerals from soil. It is the major part of root. The walls of cells are not elastic. As the cells of root hair zone become mature, the root hairs shrivel and become non-functional. The enlarged cells undergo maturation and differentiation into different types of primary tissues of the root *i.e.* cortex, endodermis, xylem, phloem etc.

KINDS OF ROOT

(a) Tap root system. The primary root and its branches constitute the tap root system. **Root which appears from radicle of embryo of seed is called tap root.** First formed root is known as **primary root**. It bears branches of first order known as **secondary roots**. The secondary roots bear branches of second order known as **tertiary roots**. The finer branches are called as rootlets. Rootlets are the ultimate root branches. The older branches occur near the base and younger branches near the apex showing the arrangement called **acropetal succession**. The primary root which is thickest at the base and tapering towards the apex, along with its branches form the **tap root system**. Tap roots of perennial plants generally grow deep into the soil and are **deep feeders.** The primary root may be sparingly or profusely branched according to the need of plant.

(b) Adventitious root system. Those roots which are produced from any other part of plant except the radicle are called **adventitious roots** (Fig. 4). Various types of adventitious roots differ in shape and functions. They may appear from base of the stem replacing the primary root or in addition to they may arise from nodes or internodes of stem. They usually appear in groups and are clustered. The adventitious roots together with its branches constitute the **adventitious root system** *e.g.* grasses, mangrove trees, banyan tree, sugarcane etc. Adventitious roots are mostly surface feeders.

MODIFICATION OF ROOTS

Roots may be modified in order to carry on some special functions. These functions differ from the normal functions assigned to roots *e.g.* storage, assimilation, additional support etc.

1. TAP ROOT MODIFICATIONS

Normal tap roots may undergo modifications in order to perform additional functions like storage of food and water, respiration, perennation, vegetative propagation etc. Storage tap roots are described below:

(a) Storage or **fleshy tap roots.** Here the roots are modified for the storage of food. Food is stored in primary root, as a result it gets swollen. Sometimes hypocotyl (embryonic region between cotyledons and radicle) also stores the food. Stem in these cases is present in the form of reduced narrow green disc. The leaves appearing from this reduced stem are called as **radical leaves.** Fleshy tap roots can be classified into following types :

(i) Conical. The base of the root is broad and gradually tapers towards the apex (Fig. 5 A). Secondary roots are present all over the swollen root *e.g.* Carrot (*Daucus carota*). The fleshy basal part of conical root is derived from hypocotyl.

(ii) Fusiform (Fig. 5 B). The root is swollen in the middle and gradually tapers towards both the ends imparting it a **spindle shaped** structure. Finer secondary

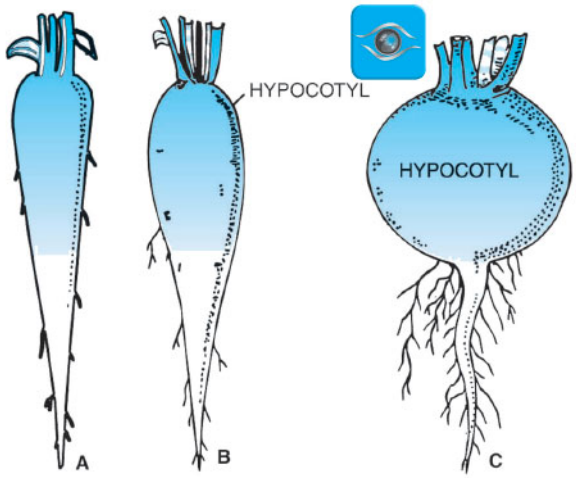


Fig. 5. Fleshy (storage) tap roots : **(A)** Conical fleshy tap root of carrot; **(B)** Fusiform fleshy tap root of English radish; **(C)** Napiform fleshy tap root of turnip.

Table 1. Differences between Fusiform and Napiform root.

Character	Fusiform root	Napiform root
1. Shape	It is spindle shaped in outline.	It is globular or spherical in outline.
2. Tapering	Apical region of root gradually tapers.	The root suddenly tapers towards apex.
3. Example	Radish	Turnip

roots appear from the apical part. In turn, they further bear root hairs. However, these are found to be absent on middle swollen and upper parts. These parts develop from hypocotyl *e.g.* Radish (*Raphanus sativus).*

(iii) Napiform. This type of fleshy root is thickest at the base and takes the spherical shape. Towards lower side it suddenly thins out. In turnip, food is stored in upper swollen part which is devoid of secondary roots hence develops from hypocotyl. Tap root shows its presence towards the narrow, thin apical side which bears secondary roots, *e.g.* Turnip (*Brassica rapa*) vern. Shalgam (Fig. 5 C), Beet (*Beta vulgaris*) vern. Chukandar.

(iv) Tuberous tap root. Root of *Mirabilis* (4 o'clock plant) and *Trichosanthes* which have no definite shape and store food are called tuberous roots.

(b) Nodulated (tuberculate) Roots. The secondary, tertiary or sometimes primary roots in sub-family Papilionatae of family Leguminosae *e.g.* Gram (*Cicer arietinum*), Groundnut (*Arachis hypogea*), Barseem (*Trifolium alexandrianum*) and Pea (*Pisum sativum*) bear small nodule like swellings (Fig. 6) The root nodules or tubercles contain nitrogen fixing bacteria (*Rhizobium leguminosarum*). These bacteria are able to convert free atmospheric nitrogen into organic compounds of nitrogen and the process is called **nitrogen fixation**. Bacteria and leguminous plant show the phenomenon of mutual benefit exhibiting **symbiosis**. These plants increase the fertility of soil by adding nitrates after the death of these roots.

(c) Pneumatophores or respiratory roots. Such roots are found in plants growing in mangroves or swamps near the sea-shore *e.g. Rhizophora, Heritiera* (vern. Sundri), *Sonneratia* and *Avicinnea*. At the base of horizontal roots, absorbing roots are present.

Pneumatophores arise vertically upwards and come out of soil and water. They bear small pores called **pneumathodes** or **lenticels** over their apical region for exchange of gases (Fig. 6B).

2. ADVENTITIOUS ROOT MODIFICATIONS

Adventitious roots do not appear from radicle of embryo, instead they arise from other parts of plant. They may appear from parts like stem or leaves. They are normally fibrous and surface feeders but some may be adapted for special functions like storage, support, assimilation etc. Some of the important types are as under :

(a) Fibrous roots. They may appear due to repeated branching of radicle. These roots are thin, almost of equal length, thread-like and arise from the base of erect stem or nodes of horizontal stem. As they do not go deep into the soil, they behave as **surface feeders.** They appear in clusters (Fig. 7) and perform the functions of fixation and absorption *e.g.* Wheat (*Triticum*), grass and maize.

(b) Fleshy adventitious roots. As in tap roots, sometimes adventitious roots also become swollen and thick due to storage of reserve food. They can be further classified into following types:

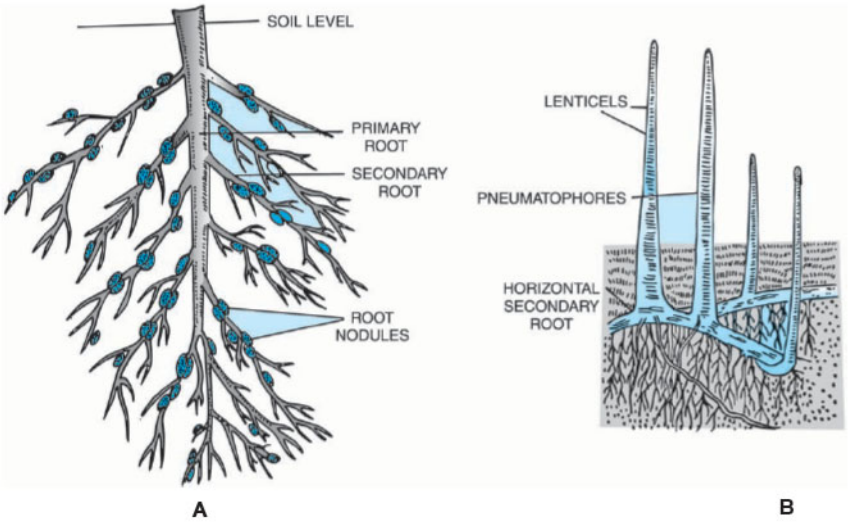


Fig. 6. A. Nodulated root of a legume; **B.** Pneumatophores with lenticels.

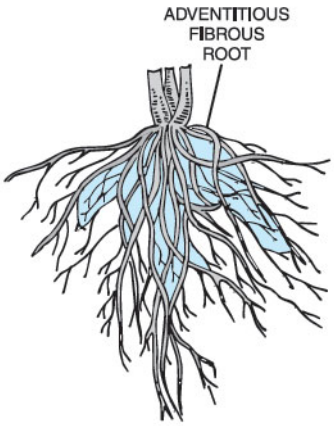


Fig. 7. Fibrous adventitious root system.

(b) Tubercular (Single Root Tubers) (Fig. 8A). When the roots become spindle shaped due to storage of food but are found singly *e.g.* sweet potato (*Ipomoea batatas*). The root tubers of sweet-potato also bear adventitious buds from which new plants can develop. Such roots are also called reproductive roots.

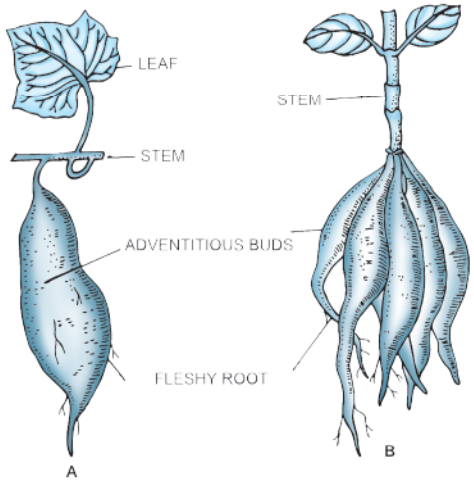


Fig. 8. A. Tubercular roots of sweet potato; **B.** Fasciculated roots of *Dahlia;*

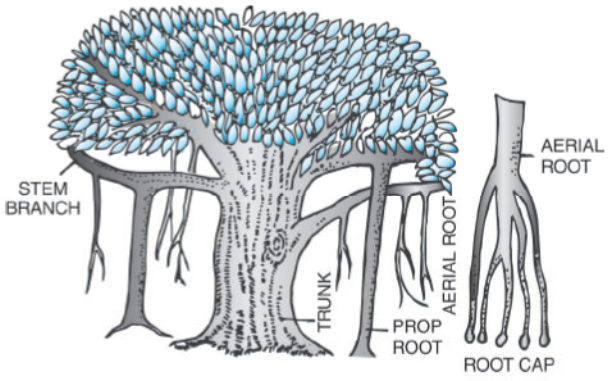


Fig. 9. Prop roots of banyan.

(c) Prop roots. These are large pillar-like roots, which appear from large horizontal branches in trees like banyan (*Ficus benghalensis*). These adventitious roots grow downwards, which may finally enter into soil. These roots are provided with root caps. These hanging roots change their colour from brown to red after absorbing water from atmosphere. As they look like pillars, hence called as **Pillar roots** (Fig. 9). Sometimes these pillar roots and main stem are of same thickness. They support or prop up the horizontal branches like pillars. Even the main trunk may die and prop roots fully replace it. With the help of prop roots banyan tree can spread over a large area and becomes almost immortal.

In small trees like screwpine (*Pandanus odoratissimus*) (Fig. 10 B) which appear on the edges of tanks, marshes

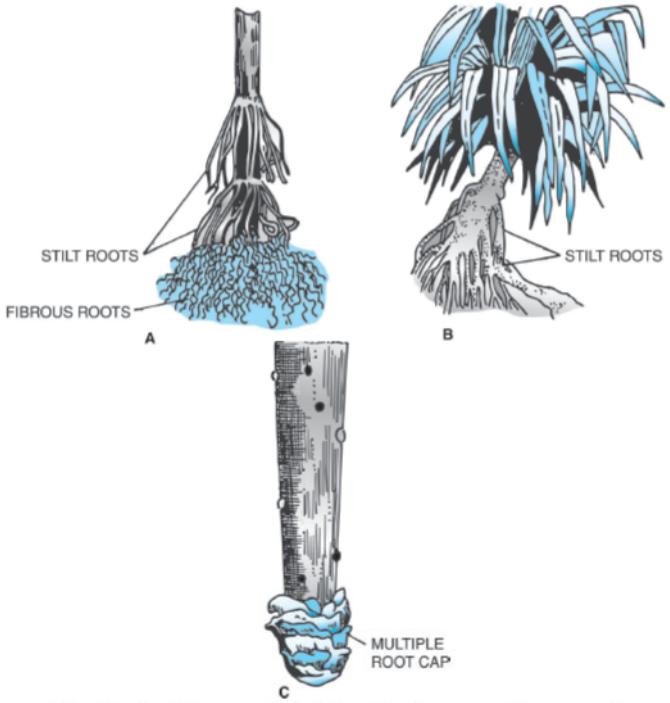


Fig. 10. A. Stilt roots in Maize, **B.** Prop or pillar roots in *Pandanus* (screw pine); **C.** Multiple root cap in *Pandanus*.

DID YOU KNOW?

- In *Dahlia* and *Asparagus*, **fascicled** or **fasciculated** roots are present which swell up due to storage of food and are found in clusters.
- Moniform or beaded roots are present in *Momordica* and *Vitis* where roots get thickened at regular intervals giving bead like appearance of necklace.
- The fleshy adventitious roots in *Orchis* and *Aconitum* assume plam (human hand) like appearance hence called **palmate roots.**
- In *Curcuma* (Turmeric) swelling occur only near the tips. They are called as **nodulose** roots.
- **Buttress** roots are present in plants like *Ficus*, *Bombax*, *Terminalia* where they appear from basal parts of main stem. They are vertically elongated and horizontally pressed.

etc., where anchorage is not very strong, pillar roots appear on the shoot of this plant which grow obliquely. These roots bear several large overlapping root caps called **multiple root caps** (Fig. 10C).

(d) Stilt roots or **brace roots.** In plants like Maize (*Zea mays)* (Fig. 10A), sugarcane (*Saccharum officinarum*), Sorghum and Bajra (*Pennisetum typhoides*) stilt roots appear from the basal nodes near the soil. They grow downwards and fix the erect stem with soil to provide extra support. They behave as ropes of a tent. Such roots are called **stilt** or **brace roots.** These plants have slender, weak, tall unbranched jointed stems called **culms.**

(e) Parasitic or haustorial roots. A plant may be total parasite (*e.g. Cuscuta*) (Fig. 11A,C) or partial parasite (*e.g. Viscum album* and *Loranthus). Cuscuta*, a total parasite shows achlorophyllous long stem, with reduced scale leaves. Being non-green, it cannot manufacture the food. For its food and water supply it depends upon hosts like *Zizyphus*, *Duranta*, *Populus* etc. The haustorial roots come in contact with the xylem and phloem of the host, and as a result water and food supply of host is diverted towards the parasite. *Viscum* (Mistletoe), a partial parasite absorbs only water and mineral elements from the host plant. Plant being green is capable of manufacturing the food (Fig. 11B).

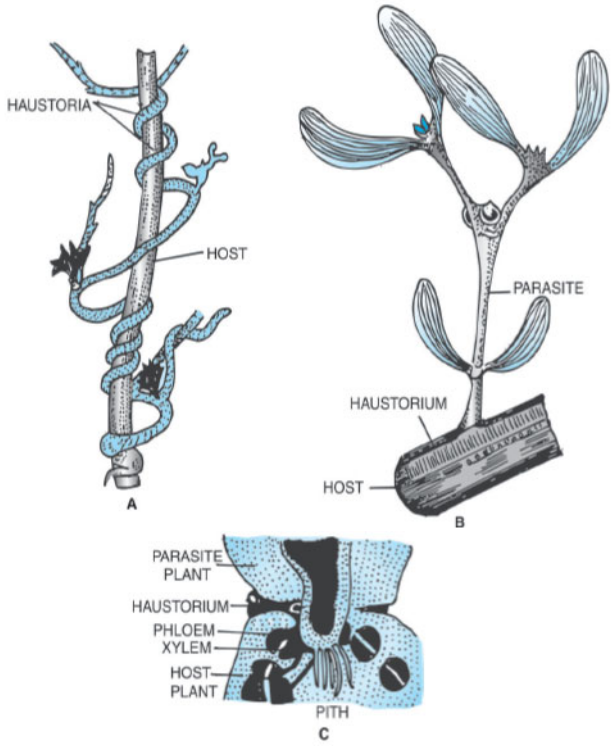


Fig. 11. Parasitic roots. **A.** Total parasite of *Cuscuta;* **B.** Partial parasite of *Viscum;* **C.** Host parasite relationship in T.S.

DID YOU KNOW?

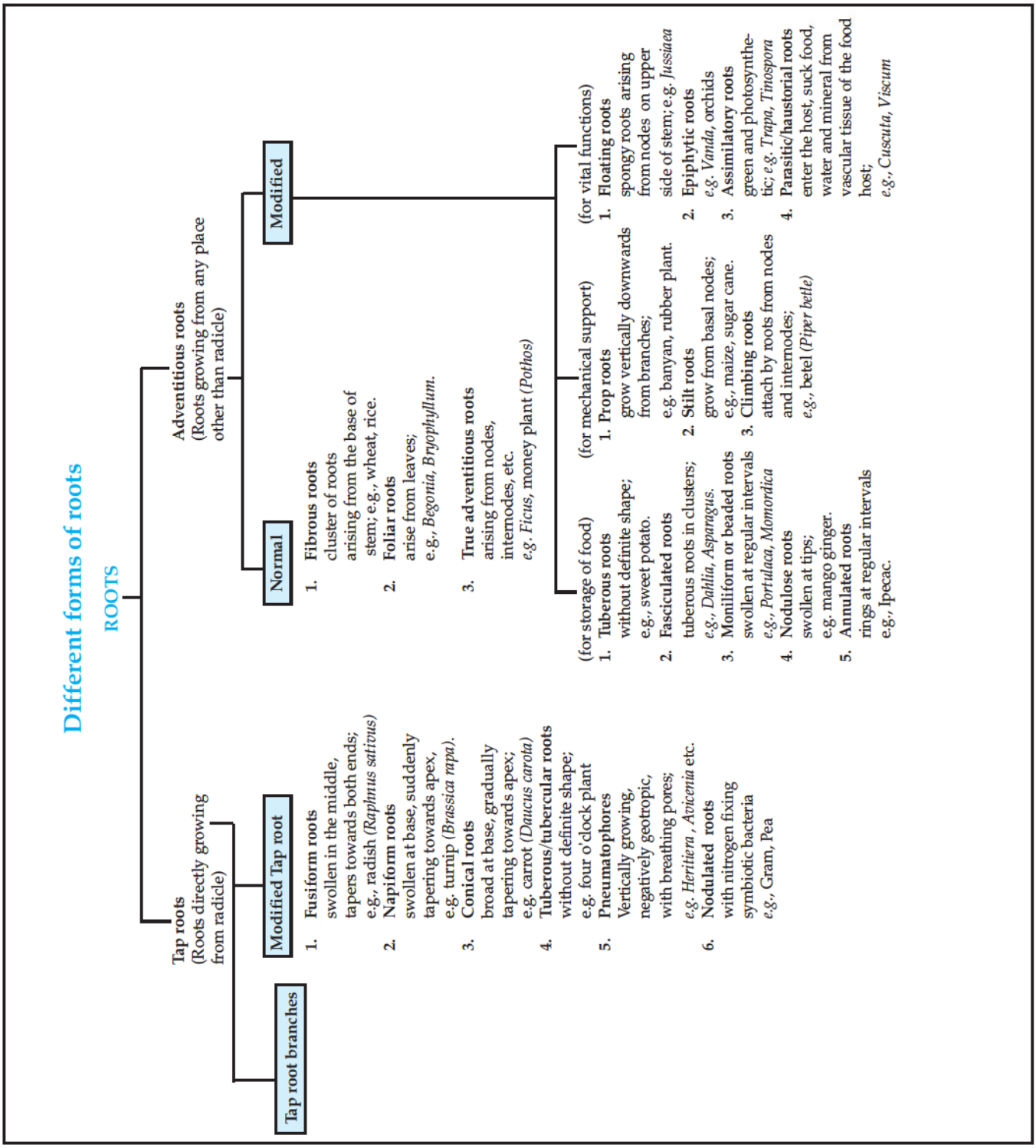
- Green **assimilatory (photosynthetic roots)** are present in plants like *Tinospora* (Gilo), *Taeniophyllum*, *Pdostemon* and *Trapa* (singhara).
- Some times roots at nodes store gases and become inflated thus help in floating on the surface of roots. Such floating roots are present in *Jussiaea* (= *Ludwigia*) and *Pistia.*
- **Epiphyllous** or **foliar** roots are present on leaves of *Begonia*, *Bryophyllum* and *Kalanchoe.*
- In Orchids like *Vanda*, some roots freely hang in air, they are provided with outer covering called **velamen** by means of which moisture from atmosphere is absorbed.
- **Clinging** or **climbing** roots help the plants in climbing by penetrating the cracks of the support e.g. *Pothos* (money plant), *Ficus pumila*, *Hedera helix*, *Piper betle* (betel), *Tecoma.*

Table 2. Differences between Tap root and Adventitious root.

Character	Tap root	Adventitious root
1. Origin	It is formed from radicle.	It arises from any part of plant other than radicle.
2. Position	It is always underground.	It may be underground or aerial.
3. Number	It has a single primary root. Other roots are borne in acropetal succession.	Cluster of roots may be present.
4. Life	Primary root persists throughout the life.	Primary root is soon replaced by adventitious roots, hence short lived.
5. Depth	It is generally deep feeder.	It is underground, such roots are usually surface feeders.

Table 3. Differences between Prop and Stilt roots.

Character	Prop roots	Stilt roots
1. Origin	Originate from upper part of stem (from horizontal branches)	Appear from basal nodes of main stem.
2. Length of roots	Very lengthy	Comparatively shorter
3. Direction	Moves vertically downwards	Develop obliquely
4. Function	Provide support just like pillars	Provide support just like ropes of a tent.
5. Thickness	Massive	Thin
6. Example	Banyan	Sugarcane, maize, *Pennisetum*, *Sorghum*



ADDITIONAL USEFUL INFORMATIONS ABOUT ROOT FOR COMPETITIVE EXAMINATIONS

- *Podostemon is a plant made up only of roots. It has some roots called **haptera** for fixing to the ground.*
- *The part of the plant that develops from radicle is called **primary root.** Lateral roots are **endogenous** i.e. arise from pericycle while lateral shoots arise exogenously i.e. arise from cortex.*
- *In hydrophytes instead of root cap, a **root pocket** is present e.g. Pistia, Lemna.*
- *Seminal roots are new roots growing near the base of radicle in monocots.*
- *In Wolffia—a floating plant (smallest angiosperm) and Utricularia–a submerged hydrophyte, there are no roots.*
- *Roots of some plants : like Pinus bear fungal hyphae and do not have root hair and root caps. Such roots are called **mycorrhizal roots.***
- *Velamen a spongy tissue on roots is characteristic of epiphytes.*
- *Root cap is continuously produced from root apex.*
- *Once lost, root pockets cannot be regenerated.*

FUNCTIONS OF ROOTS

Main or primary functions

1. **Anchorage.** They help in fixing the plant firmly with the soil.
2. **Absorption of water and minerals.** The roots absorb water and mineral salts.
3. **Prevention of soil erosion.** It binds the soil.

Secondary functions

1. **Root floats.** They help in floating *e.g. Jussiaea.*
2. **Reproductive roots.** They can help in multiplication of plant *i.e.* vegetative propagation *e.g.* **sweet potato** and *Dahlia.*
3. **Hygroscopic roots.** They can absorb the water from atmosphere with the help of special tissue velamen *e.g. Vanda, Vanilla.*
4. **Assimilatory roots.** They help in synthesis of food *e.g. Podostemon, Tinospora.*
5. **Respiratory roots.** They may serve for respiration *e.g. Rhizophora.*
6. **Storage of food.** They can store the food by becoming fleshy *e.g.* Radish, Turnip, *Dahlia* etc.
7. **Helping plants to climb.** They may help in climbing the weak stem *e.g. Pothos, Tecoma* and **Ivy.**
8. **Providing additional support.** Prop roots and stilt roots provide additional support to plants *e.g. Ficus benghalensis, Pandanus, Zea mays* etc.
9. **Mycorrhizae.** Some roots bear fungal hyphae to form mycorrhizae. Such roots help in absorption of nitrogen and phosphorus from organic sources *e.g. Pinus* and *Quercus.*
10. **Haustorial roots.** In plants like *Cuscuta*, roots penetrate the host stem to obtain food and water, thus behaving as haustorial roots.

STEM

Stem is the main axis of shoot system of plants. It can be defined as the **ascending part of shoot axis which is negatively geotropic, positively phototropic and develops from plumule of embryo**. There are two chief functions of stem:

1. Conduction of water, mineral and food material.
2. Production and support of leaves and reproductive structures.

A stem with its leaves is called **shoot**. Entire stem with all its branches and leaves is known as **shoot system**. Stems usually grow above the soil and termed as **aerial stems**. Sometimes the stem may remain underground to be called as **underground** or **subterranean stem**. There are examples where the stem is weak, becomes prostrate and trails on the ground. In a few cases this weak stem may twine around a support or climb with the help of some special climbing organ as tendril, thorn, hook, spine etc. In all these cases aerial stems are not strong enough to become **erect**. A stem is differentiated into **nodes** and **internodes** which alternates with each other. Leaves arise from nodes. Internode is the portion of stem between two nodes. Nodes are usually recognised by the presence of leaves. But in some cases as bamboos the nodes become very distinct and exhibit clear joints. The internodes of such jointed stems are called **culms.**

Characteristics of stem

1. Stem bears leaves, flowers and fruits.
2. It represents the ascending part of the shoot axis.
3. Stem is normally positively phototropic in nature.
4. It bears distinct nodes and internodes.
5. Stem bears buds.
6. The branches and leaves appear exogenously on stem.
7. It may bear multicellular hairs on external surface.
8. Scale leaves or adventitious roots may appear on stem.

BUD

Bud can be defined as **young undeveloped shoot consisting of a short stem and a number of tender leaves arching over the growing apex.**

Or

Bud is a compact young shoot consisting of short stem overlapped by crowded immature leaves which are surrounding the growing point.

The buds are generally small but in some buds, like that of cabbage (Fig. 12 C) (*Brassica oleracea* var. *capitata)* are quite large. In the upper angle between the point of juncture of a leaf stalk, with a stem is located, as rule, a bud. The angle between the leaf stalk and the stem is termed the leaf axil. Bud found in leaf axil is called **axillary** (Fig. 12A). Since they are found along the sides of a stem, they come under the category of lateral buds.

Sometimes some extra buds are found by the sides of axillary bud and are known as **accessory** buds (Fig. 12A). Occasionally buds appear at places other than leaves. Such buds are called **adventitious**. The adventitious buds may appear on stem (**cauline**) from roots (**radical**) or from leaves (**epiphyllous**) (Fig. 13). They sometimes develop as a result of injury. In **naked** buds the meristematic tissue is exposed to air without any protective covering other than rudimentary leaves. In some plants the buds are **covered** with overlapping scales, known as **bud scales**. These scales protect the meristematic tissue from desiccation.

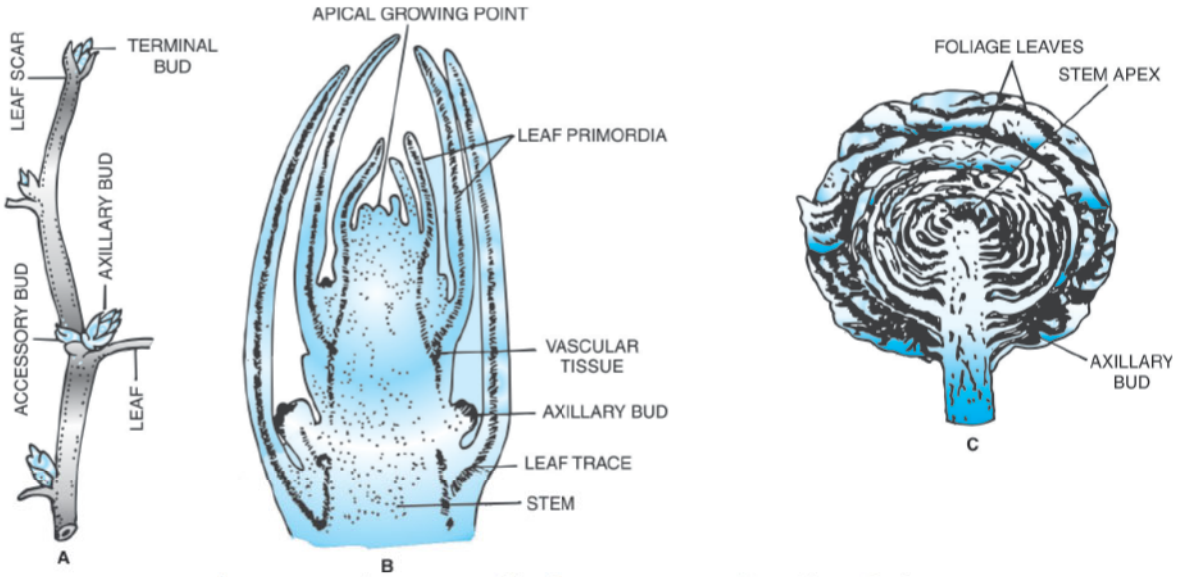


Fig. 12. A. Bud; **B.** Terminal bud in L.S.; **C.** L.S. of a cabbage bud.

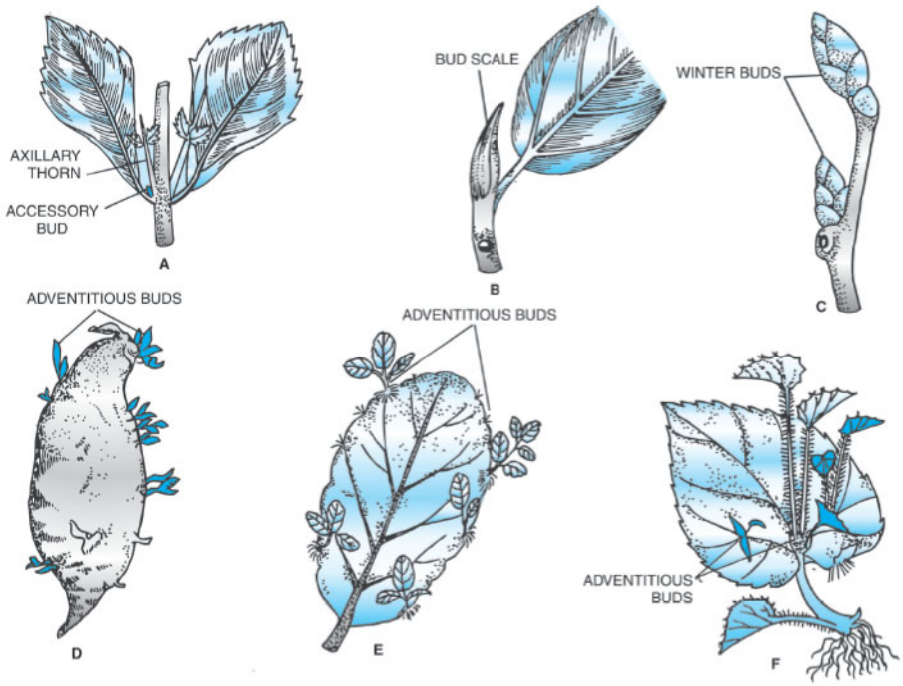


Fig. 13. Buds **A.** Accessory bud in *Duranta* **B.** Bud scale on scaly bud of *Ficus* **C.** Winter buds **D.** Adventitious buds on tuberous roots of sweet potato **E.** and **F.** Adventitious buds on leaves of *Bryophyllum* and *Begonia* respectively.

On the basis of activity, buds may be **active** or **dormant**. Dormant buds usually remain inactive. They during unfavourable season do not give branches. Buds differ also in the **nature** of structures which are produced by them. They may be **flower** buds, which produce only flowers. They are called **vegetative** buds or branch buds when they grow into new length of twigs bearing leaves. They are **mixed** buds when they sprout to produce twigs bearing both leaves and flowers. Fleshy buds which take part in vegetative reproduction are called **bulbils** *e.g. Agave*. Fleshy buds functioning in perennation in aquatic plants are called **turions** *e.g. Potamogeton*. Buds may also be modified into **tendrils** *e.g. Passiflora* or **thorns** *e.g. Duranta*.

TYPES OF STEM

Based on branching plants may be classified into four categories :

(i) Culm. The stem is unbranched showing distinct nodes and internodes imparting it a jointed appearance *e.g. Bambusa arundinacea* (bamboo).

(ii) Columnar (Caudex) (Fig. 14A). In such cases trunk is unbranched erect, cylindrical and marked with scars and remnants of fallen leaves. It bears a crown of leaves at its apex. *e.g.* Fan palm (*Borassus flabellifer*), Nut palm vern. Supari (*Areca catechu*) and coconut (*Cocos nucifera*).

(iii) Excurrent. In such cases lateral branches do not compete with growth of main stem. Branches appear acropetally. Thus a tree receives cone–like appearance *e.g. Pinus, Casurina, Eucalyptus* (Fig. 14B).

(iv) Decurrent or **deliquescent**. When some of the lateral branches grow more vigorously, the trunk disappears after some distance due to suppression of growth of terminal bud, the form is called **decurrent** *e.g.* Mango (*Mangifera indica*), Shisham (*Dalbergia*) and Banyan (*Ficus benghalensis*) (Fig. 14C).

(v) Scape. Naked flowering stem arising from the ground without leaves is called **scape** e.g. Onion *(Allium cepa)* and banana *(Musa paradisiaca)*.

(vi) Climbers. Such plants attach themselves to nearby objects by means of some special structures like **tendrils** e.g. wild pea, **hooks** e.g. *Bougainvillea.*

MODIFICATIONS OF STEMS

Along with **erect** forms of stems such as **culm, columnar, excurrent** and **decurrent** types, the stems are of three kinds :

(a) Reduced stems, **(b)** Underground stems, and

(c) Weak stems.

(A) REDUCED STEMS

The stem is highly reduced in the form of a disc and lies above the base of the root. Nodes and internodes are not distinguishable and leaves appear crowded together on these stems *e.g. Daucus carota* (Carrot), *Raphunus sativus* (Radish) and *Brassica rapa* (Turnip). Leaves appearing on reduced stem are called **radical leaves.**

(B) UNDERGROUND STEMS

Mostly herbaceous plants are short living annuals because they find it difficult to survive above ground during unfavourable seasons of the year. However, during unfavourable season when aerial parts die, underground parts remain safe. They usually store food and can be vegetatively propagated. Such underground stems are specially adapted for perennation (to tide over the unfavourable season). The underground stem though non-green in colour can be easily distinguished from root by the presence of :

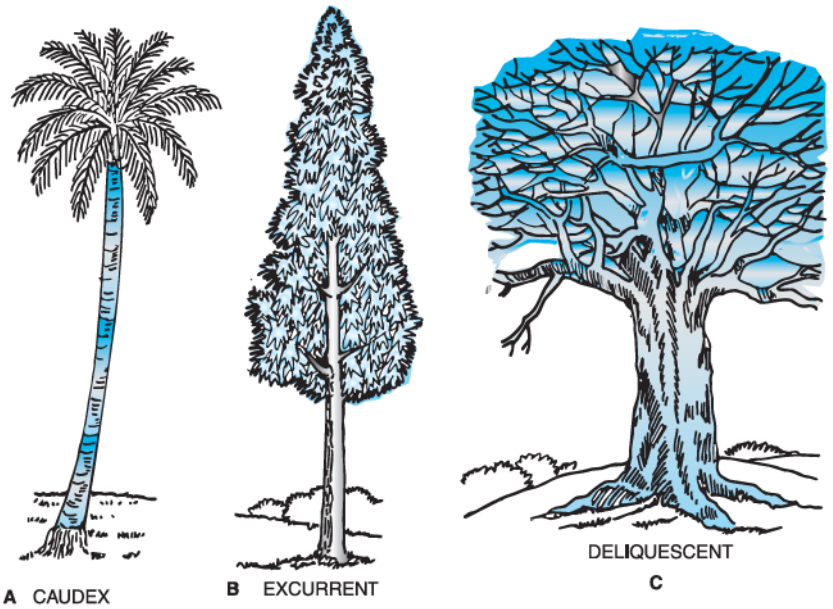


Fig. 14. Types of trees **A.** Caudex; **B.** Excurrent; **C.** Decurrent or deliquescent.

(a) Nodes and internodes. **(b)** Scaly leaves. **(c)** Axillary and terminal buds.

There are four principal kinds of underground stems. viz. **rhizome (Root stock), corm, bulb** and **tuber.**

1. Rhizome. Rhizome or root stock is a dorsiventral, horizontal stem growing beneath the surface of soil. Though erroneously known as root stock, rhizomes are strictly stem in the sense that they bear nodes and internodes. They bear scaly leaves, axillary buds and often bear roots at their nodes. Rhizomes are perennial structures. During favourable season, some of their buds develop into leafy shoots, while others form new subterranean shoots. Rhizomes produce adventitious roots in profusion. Its direction is usually horizontal, but in some cases it grows in vertical direction **(root stock)** or obliquely placed and **unbranched** *e.g. Musa paradisiaca* (Banana) and *Dryopteris* (Fern).

Rhizomes are usually fleshy due to storage of food. The rhizome which is placed horizontally and usually branched is called **straggling rhizome**. The branching of rhizome may be **racemose** constituting monopodial axis rhizome *e.g. Saccharum aurndinaceum*, Lotus. Branching is **cymose** giving the appearance of **sympodial** axis rhizome *e.g. Zingiber officinale* (ginger) (Fig. 15 D) and *Curcuma longa* (turmeric) and *Canna indica* (Fig. 15 A) and water lily.

2. Corm. Corm is short, thick and unbranched underground stem with stored food material. It grows vertically and covered by thin sheathing leaf bases of dead leaves called **scales**. The corm bears buds at their nodes. These buds are responsible for giving off adventitious roots. Corm serves the functions of food storage, vegetative propagation and perennation. Corm is more or less rounded in shape or often somewhat flattened from top to bottom. Corm is found in *Amorphophallus* (Kanda) (Fig. 16D), *Alocasia*, *Gladiolus*, *Colocasia* (Kachalu), *Crocus* (Saffron vern. kesar) (Fig. 16C), *Colchicum* (Meadow saffron) Zamikand, and *Freesia* (Fig. 16A). The nodes in all these cases are circular. Axillary buds in *Colocasia* (Fig. 16B) are very prominent.

3. Bulb. Bulb may be regarded as a short underground stem with fleshy leaf base called scales. Stem is very much reduced and becomes disc like. The discoid stem is convex or conical in shape and bears highly compressed internodes. These node bear fleshy scales. On the upper side, disc bears terminal bud surrounded by number of leaves. The axillary buds are present between the axis of leaves. The adventitious roots are borne on the lower side of the disc. The bulbs are of two types:

(a) Tunicated *(b)* Scaly.

(a) Tunicated. In tunicated bulb, the scale leaves overlap one another with a dry scale called **tunic** on the outer side. Bulb is called **simple tunicated** or **layered** when the scale leaves are arranged in a concentric manner and form a series of rings. Axillary buds are borne in the axils of fleshy scales. Such bulbs are surrounded by a common sheath of membranous structure **tunic** on outer side *e.g. Allium cepa* (onion) (Fig. 17A), *Narcissus*

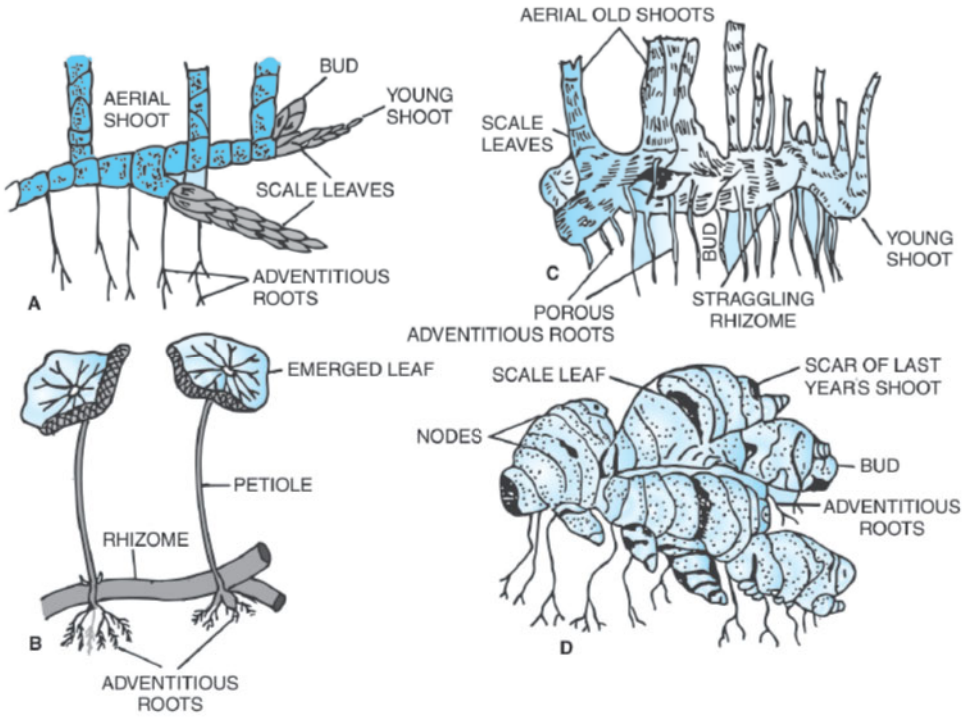


Fig. 15. Rhizome. **A.** *Canna*; **B.** Lotus (*Nelumbium*); **C.** Kanna (*Saccharum aurndinaceum*); **D.** Ginger.

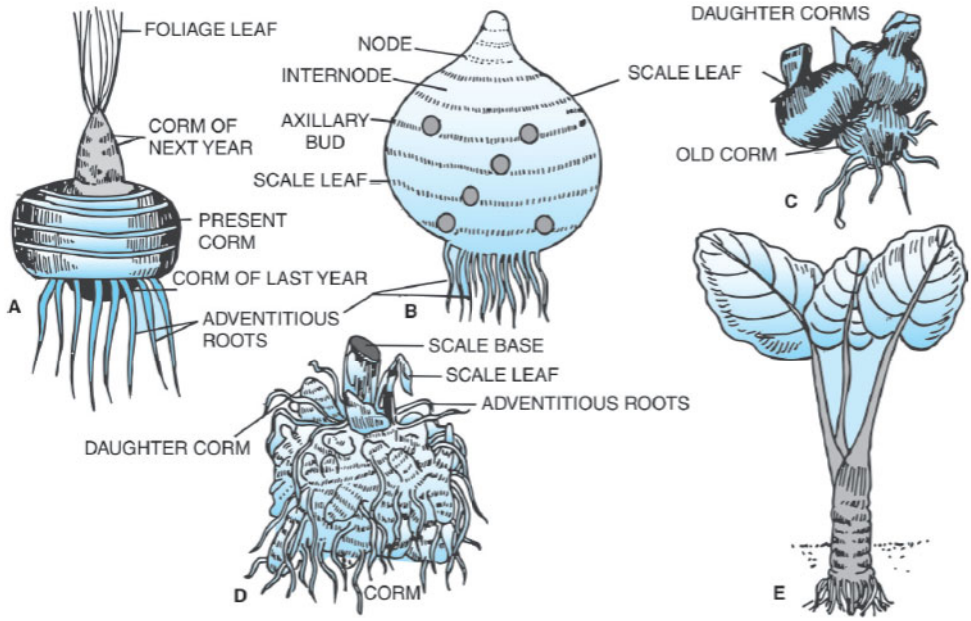


Fig. 16. Corms. **A.** *Freesia*; **B.** *Colocasia*; **C.** *Crocus*; **D.** *Amorphophallus*; **E.** *Alocasia*.

and *Tulipa* (Tulip). **Compound tunicated** bulbs as in *Allium sativum* (garlic) (Fig. 17D) buds become fleshy. They bear their individual tunics. Such fleshy buds are called **bulblets** or **cloves.** These concentric rings of tunicated bulblets are in turn surrounded by overlapping tunics. That is why such type of bulbs are called as compound tunicated bulbs.

(b) Scaly or **imbricate**. In such cases scale leaves are not concentric. Scale leaves are narrow, small and separated. They are loosely arranged and overlap each other only at their margins. They lack enveloping tunic *e.g. Lilium bulbifera* (Lily) (Fig. 17G).

4. Tuber. When the underground stem becomes enlarged at the growing tips by the accumulation of stored food, commonly starch, tubers are produced *e.g. Solanum tuberosum* (Potato) (Fig. 18). The eyes of potato

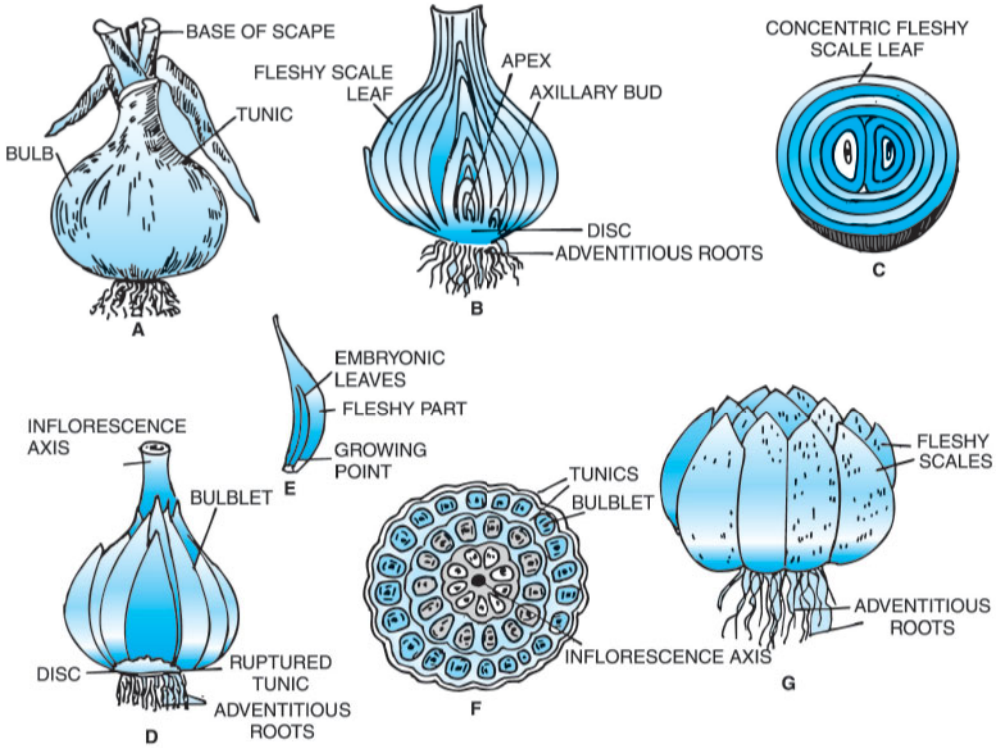


Fig. 17. Bulb. **A.** Entire bulb of Onion; **B.** L.S. Onion bulb; **C.** T.S. Onion bulb; **D.** Compound tunicated bulb of Garlic; **E.** L.S. Bulblet; **F.** T.S. bulb of Garlic; **G.** Scaly bulb of Lily.

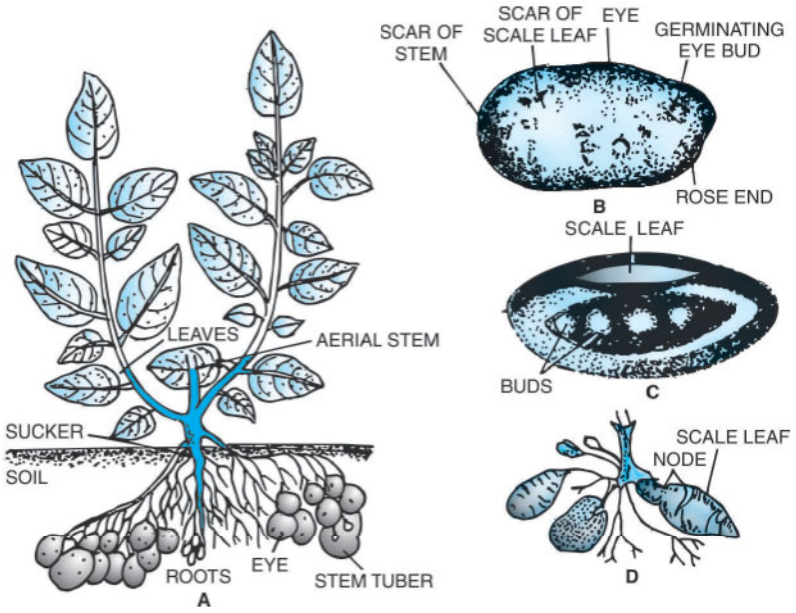


Fig. 18. Tuber (Potato). **A.** Stem tuber formation; **B.** Potato tuber; **C.** Enlarged eye; **D.** Stem tuber of *Helianthus tuberosus.*

are nodes at each of which 1-3 buds are produced in the axils of small scaly like leaves. Tubers are responsible for storing the food. At the skin of potato a number of lenticels are present which help in gaseous exchange. Potatoes are propagated by cutting of tubers. Each piece of tuber should contain an eye or node for vegetative propagation. The eyes are more crowded towards distal end (rose end) and tuber is terminated by an apical bud. The point of attachment of the tuber to stem is represented by a scar which lies opposite to the apical bud. Tubers are also found in *Cyperus rotundus*, *Helianthus tuberosus* and *Stachys tuberifera.* Initially adventitious roots are absent on tubers but at the time of germination, eye buds develop into small shoots from the bases of which adventitious roots appear.

SUB AERIAL MODIFICATIONS OF STEM

In such cases the stems are delicate, thin, weak and unable to stand erect. They cannot expose their leaves to sunlight while competing with erect plants. To overcome this problem they may grow **prostrate** on ground or climb up on support as **climbers** and thus can be classified as :

(i) Prostrate weak stems and **(ii) Climbing weak stems**

(i) Prostrate weak stems

Sometimes the stems are thin, delicate, weak and are unable to stand erect. They may grow prostrate on ground or may become buried in the top soil. These branches bear adventitious roots and aerial branches at their respective nodes. These plants can be propagated easily by means of fragments of special branches. Such plants are usually known as **creepers.** They are of following types :

1. Runner 2. Sucker 3. Stolon 4. Offset 5. Trailer

1. Runner. It grows prostrate in all directions above the soil level. Nodes bear scale leaves. It has a creeping stem with long internodes. On the lower sides, nodes bear adventitious roots. Runner develops from the axils of lower leaves of aerial stem which sends slender horizontal branches in the form of runners. When older parts of plant die, the branches separate from parent plant and form independent plants *e.g. Cynodon dactylon* (Doob grass) (Fig. 19A) and *Oxalis* (Fig. 19B).

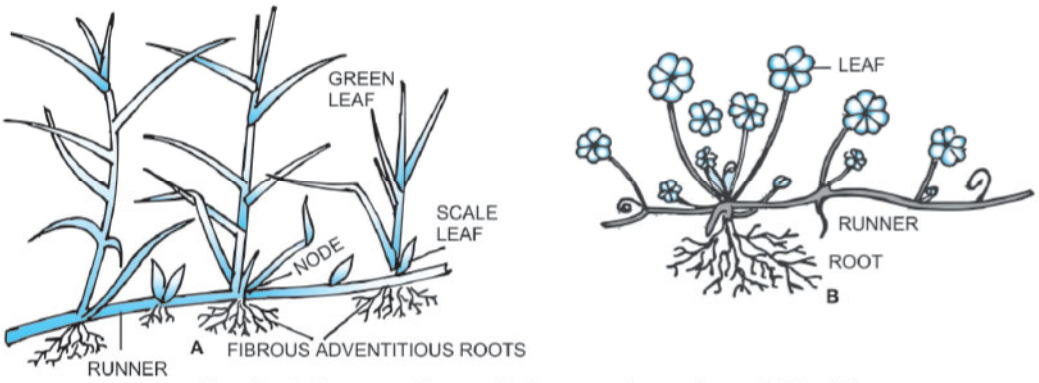


Fig. 19. A. Runner of grass **B.** Runner of wood sorrel *(Oxalis).*

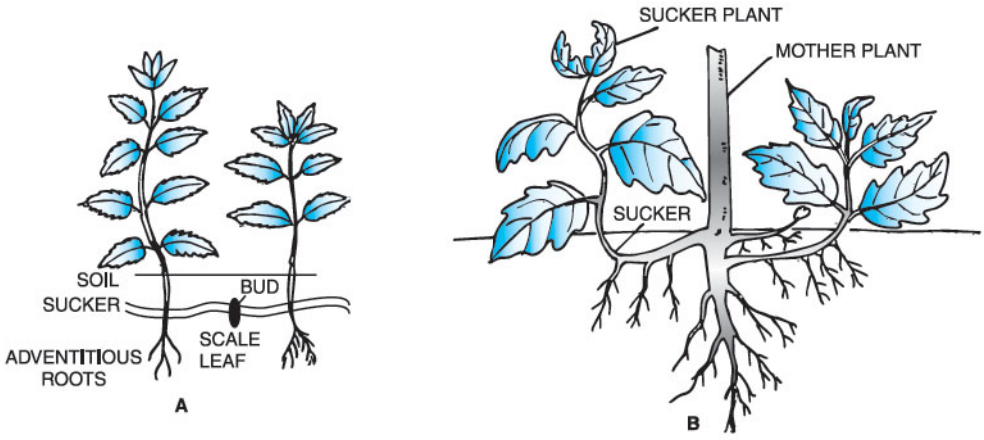


Fig. 20. A. Sucker of mint; **B.** Sucker of *Chrysanthemum.*

2. Sucker. Sucker like runner develops from the nodes of horizontal or vertical branch of main stem. But it usually moves horizontally below the soil. It also develops from the axis of scaly leaves from axillary buds. Adventitious roots develop from lower side of nodes.

Some of the branches come above the soil obliquely and produce green leaves to form aerial shoots. So the sucker can be rightly called as underground runner, *e.g. Chrysanthemum* (Fig. 20B) and *Mentha* (Mint) (Fig. 20A). Some authors consider mint as a runner. Sucker is more shorter and stouter than a runner.

3. Stolon. It is a slender lateral branch which appears from the lower part of main axis. This lateral branch grows aerially for some distance and becomes arched and finally touches the ground to give rise to new shoot with the help of its terminal bud. It also bears roots to get fixed with the soil *e.g. Fragaria* (wild strawberry) (Fig. 21), *Jasminum* (Jasmine) and peppermint.

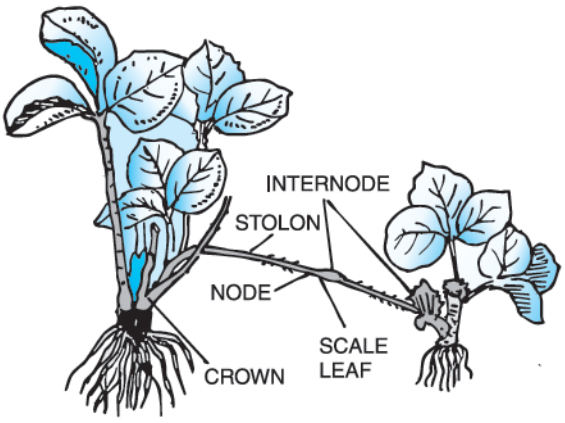


Fig. 21. Stolon of Strawberry (*Fragaria*).

4. Offset. Offset is more shorter and thicker. It is usually found in aquatic plants like *Eichhornia* (water hyacinth) and *Pistia* (Fig. 22). An offset bears a cluster of leaves near the water or ground level and gives adventitious roots inside water or ground from all nodes.

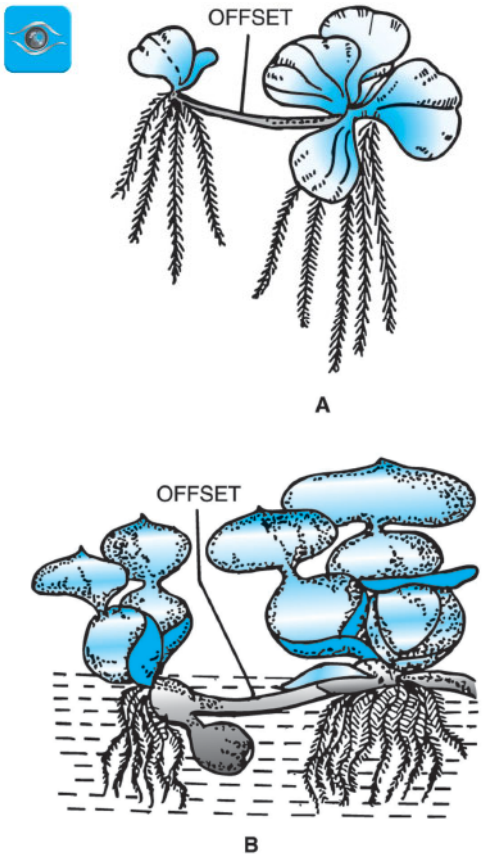


Fig. 22. Offset. **A.** *Pistia*; **B.** *Eichhornia.*

AERIAL MODIFICATIONS OF STEM

(ii) Climbing weak stems

They are of three kinds—twiners, lianas and climbers :

1. Twiners. The stem is long, flexible and go up twining around the support by a special type of growth movement which makes the stem coil around the support *e.g. Dolichos lablab* (Sem) (Fig. 23), *Convolvulus arvensis* and *Ipomoea quamoclit.* The twining may be clockwise or anticlockwise.

2. Lianas. They are thick and woody twiners in which the young stems are sensitive and flexible and coil around the support *e.g. Bauhinia vahli, Tinospora, Hiptage.*

3. Climbers. The weak stems climb upwards with the help of various parts which act as climbing organs *e.g.* tendrils, spines, thorns, hooks and roots. They may be classified into following types :

(a) Tendril climbers. Tendrils are green thread–like sensitive structures which can coil around the support and help the weak stemmed shoots to climb up. Tendrils may be modified stems (Fig. 25) or leaf (Fig. 37).

(b) Root climbers. The weak stem cling to the support by adventitious roots *e.g. Pothos* (money plant), *Tecoma, Hedera nepalensis* (Ivy), *Piper betle* (Fig. 24).

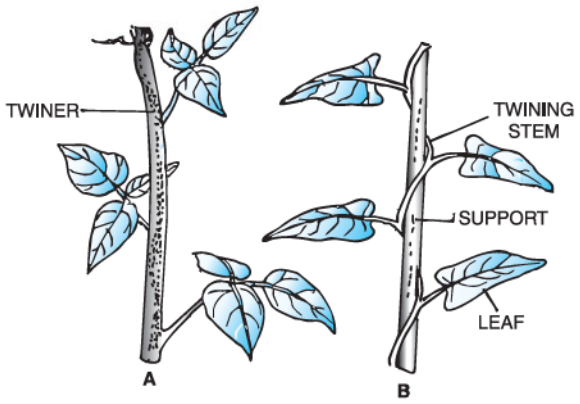


Fig. 23. A. Twiners of *Dolichos lablab.* **B.** *Convolvulus.*

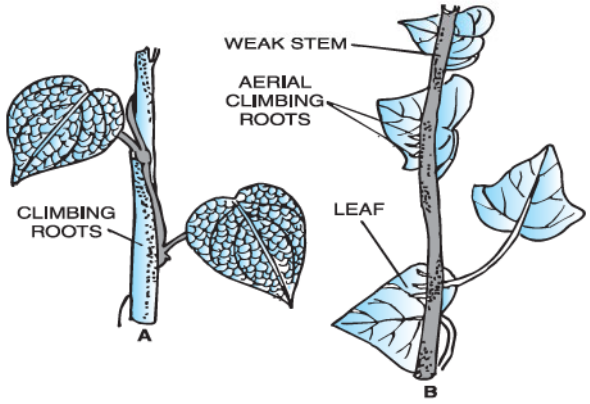


Fig. 24. Root climbers. **A.** *Piper betle* **B.** *Hedera nepalensis* (Ivy).

Modifications of stem

I. Underground modifications

1. **Rhizome**
   Sub-terranean,
   grows horizontally;
   e.g., Ginger (*Zingiber officinale*), Turmeric
2. **Tuber**
   Swollen stem tip, axillary buds present;
   e.g. Potato (*Solanum tuberosum*)
3. **Corm**
   Sub-terranean, grows vertically;
   e.g., Gladiolus, saffron, *Colocasia, Crocus, Alocasia*
4. **Bulb**
   Stem condensed, leaves scaly and fleshy
   e.g., Onion *(Allium cepa)*, Garlic *(Allium sativum)*

II. Sub-aerial modifications

1. **Runner**
   Prostrate, creeping, rooting at nodes; e.g, doobgrass, *Oxalis*
2. **Sucker**
   Arises from basal underground stem, grows obliquely upwards;
   e.g., Mentha, Chrysanthemum
3. **Stolon**
   Sub-terranean, roots at nodes and gives off aerial branches;
   e.g., Fragaria, Jasminum
4. **Offset**
   Internodes short and thick, group of leaves at nodes;
   e.g., Water Hyacinth (Eichhornia)

III. **Aerial modifications**

1. **Tendril**
   Thin, wiry, leafless, spirally coiled structures;
   e.g., Passiflora, grapevine
2. **Thorn**
   Hard, straight, pointed axillary branch;
   e.g., Duranta, Citrus
3. **Phylloclade**
   Stem modified into leaf-like structures;
   e.g., Opuntia
4. **Cladode**
   Phylloclade of one or two internodes;
   e.g., Asparagus, Ruscus
5. **Bulbil**
   Modified vegetative or floral buds,
   e.g., Dioscorea

Table 4. Differences between Runner and Sucker.

Character	Runner	Sucker
1. Nature	Runner is a prostrate, aerial green stem.	Sucker is almost underground, non-green stem.
2. Internodal length	It is the main axis of plant with long internodes.	It is only the specialised branch of main axis and bears short internodes.
3. Reproduction	It is only helpful in vegetative propagation, *e.g.* Lawn grass.	It is helpful in vegetative propagation as well as perennation *e.g.* Mint.

Table 5. Differences between Stem and Root.

Character	Stem	Root
1. Origin	It develops from **plumule.**	It develops from **radicle.**
2. Leaves and buds	It bears leaves and buds.	It does not bear leaves and buds.
3. Nodes and internodes	Nodes and internodes present.	Nodes and internodes absent.
4. Hairs	Hair if present are multicellular.	Root hair are unicellular.
5. Root cap	No cap present at the apex.	Root cap present at the apex.
6. Colour	Often green in colour.	Never green in colour.
7. Origin of branches	Branches have exogenous origin.	Branches have endogenous origin.
8. Phototropism and geotropism	It is positively phototropic and negatively geotropic.	It is negatively phototropic and positively geotropic.
9. Formation	Stem usually forms shoot system in the air.	Root usually forms root system in the soil.

Table 6. Differences between Rhizome and Corm.

Character	Rhizome	Corm
1. Position	Underground stem is well developed, generally well branched rarely unbranched.	Underground stem is not well developed and unbranched.
2. Nodes and internodes	Stem and branches bear distinct nodes and internodes.	Nodes and internodes are distinct but circular.
3. Storage	Food material is stored in entire stem and branches.	Food material is stored in main stem.
4. Adventitious roots	Adventitious roots arise from the part which is in touch with soil to keep the rhizome in horizontal position.	Adventitious roots may arise all over the body to keep the corm in vertical position.
5. Buds	Buds are borne in the axils of dry scale leaves.	Buds are borne in the axils of scale.
6. Scale leaves	Scale leaves are thin, brownish and membranous.	Scale leaves are thin, membranous and brownish.
7. Storage in scale leaves	Scale leaves do not store food material.	Scale leaves do not store the food.
8. Duration of scale leaves	Scale leaves are persistent in nature.	In corms also, scale leaves are persistent.
9. Examples	Examples of rhizome are fern, ginger, etc.	Examples of corms are *Colocasia*, *Crocus* etc.

Table 7. Differences between Tuber and Bulb.

Character	Tuber	Bulb
1. Size	The stem is well developed.	Stem is reduced to form a disc.
2. Branching	Tuber is unbranched.	Bulb is also unbranched.
3. Storage	Food material is stored in apices of branches.	Food material is stored in scale leaves, buds etc.
4. Adventitious roots	Adventitious roots are not present but they appear when it is sown in soil.	Adventitious roots are present at the base of reduced stem to keep the bulb vertical in the soil.
5. Under ground branches	Main stem gives underground sucker-like branches. Tips of these branches store food and swell up to form tubers.	Branches are absent.
6. Nodes	Distinct nodes are present in the form of eyes on tubers.	Distinct nodes and internodes are absent.
7. Scale leaves	Scale leaves in eyes are thin, membranous and brown.	Bases of leaves become fleshy to store the food. Outermost scale leaf forms covering to constitute tunic.
8. Examples	Examples of tubers are potato and *Helianthus tuberosus.*	Examples of bulb are onion and garlic.

Table 8. Differences between Stem tuber and Root tuber.

Character	Stem tuber	Root tuber
1. Nature	It is a swollen underground stem.	It is a swollen root.
2. Position	They are borne at the tips of underground stem branches.	They develop adventitious roots from any part of the stem.
3. Roots	Stem tubers do not bear any roots.	Many finer root branches may arise from it.
4. Nodes and internodes	They are differentiated into nodes and internodes.	Nodes and internodes are absent.
5. Eyes, buds	Each node is represented by an eye. It consists of a scaly leaf with one or more axillary buds.	Scaly leaves and axillary buds are absent. However, adventitious buds may be present.
6. Apical bud	An apical bud is present.	Apical bud is absent.
7. Chlorophyll	On exposure to light, the stem tubers may develop chlorophyll.	Chlorophyll does not develop in a root tuber.
8. Resemblance	Anatomically, it resembles a stem.	Anatomically, it resembles root.

Table 9. Differences between Twiner and Climber.

Character	Twiner	Climber
1. Response	Twiner is sensitive to contact.	Climber is not sensitive to contact.
2. Specialised organ	No specialised climbing structures appear on twiners.	Specialised climbing structures appear on climbers.
3. Climbing organ	Twiner climbs by twining (coiling) around the support.	Climbing organs such as tendrils, thorns, spines, prickles, hooks etc. help in climbing on the support.

(c) Hook climbers. In *Bignonia unguis cati* (Fig. 40B) three terminal leaflets of compound leaf are modified into claw–like hooks which help the plant in climbing.

(d) Spine or **Thorn climbers.** In such cases (Fig. 26), the climbing organs are thorns, prickles or some other spiny structures. They help the plants to climb up *e.g.* Climbing rose (with curved **prickles**), *Asparagus* (with leaf **spines**), *Bougainvillea* (with extra axillary **thorns**), *Calamus* (with leaf sheath **spines**). Thorn climbers are also known as **Scramblers**.

SPECIAL MODIFICATIONS OF STEM

The stem may be modified to perform diverse functions according to specific requirements of a plant. Such modified stems can be recognised by :

(a) exogenous type of branching

(b) by presence of leaves and buds

(c) by their axillary origin

(d) by their internal structure.

Following are the few important stem modifications :

1. Stem tendrils. The weak stems climb up with the help of thread-like greenish, sensitive structures called as **tendrils.** They are slender and spirally coiled (spring like structures). A tendril may be a modification of stem, branch, a leaf or part of leaf.

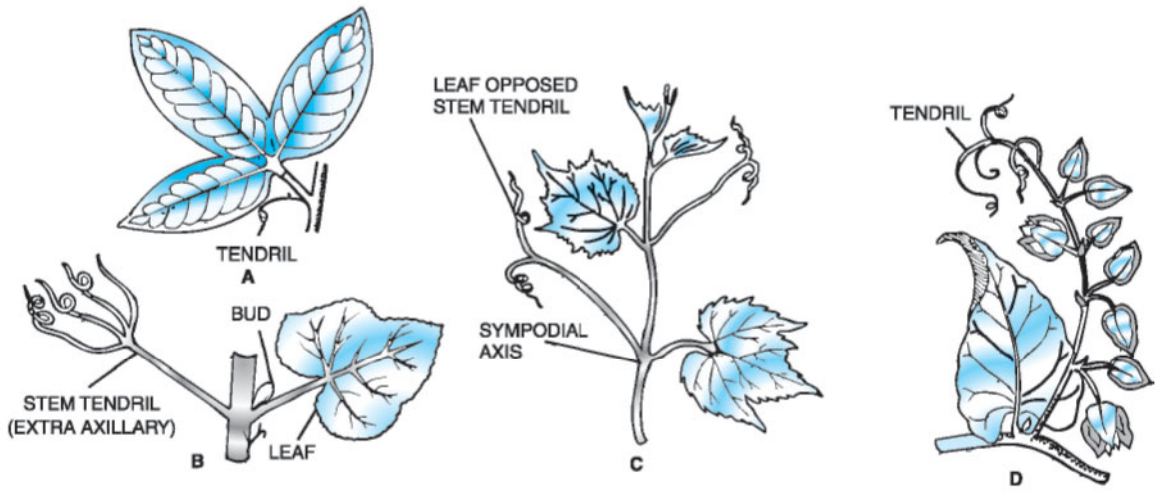


Fig. 25. Stem tendrils. **A.** *Passiflora.* **B.** *Cucurbita.* **C.** Grapevine. **D.** *Antigonon.*

Some stem tendrils are :

(a) Axillary branch tendril *e.g. Passiflora* (passion flower) (Fig. 25A).

(b) Extra axillary branch tendril *e.g. Cucurbita*, cucumber, pumpkin, watermelon etc. (Fig. 25B).

(c) Sympodial axis tendril *e.g. Vitis vinifera* (grapevine) (Fig. 25C).

(d) Floral bud tendril *e.g. Antigonon* (Fig. 25D).

2. Stem thorns. Sometimes the stem branches which appear from axillary buds are deprived of their normal growth and are modified into sharp pointed structures called **thorns.** Thorns are deep seated structures with vascular connections. **Prickles** represent the superficial outgrowths on epidermis. **Spines** are usually modified leaves or part of leaves. Thorns are very commonly found on plants like *Citrus* (Fig. 26 C), *Bougainvillea* (Fig. 26D), *Duranta* (Fig. 26A), *Flacourtia* (Fig. 26E) and *Aegle marmelos.*

3. Phylloclade. It is a green, flattened or cylindrical stem which takes the form and function of leaf. They contain chlorophyll and are responsible for carrying on photosynthesis. It bears succes-sion of nodes and internodes at long or short intervals. Phylloclades are found in xerophytic plants where the leaves either grow feebly or fall off early or modified into spines *e.g. Opuntia* (Fig. 27A), *Muehlenbeckia* (Cocoloba) (Fig. 27D), *Epiphyllum*, (Fig. 27 C), *Euphorbia royleana* (Fig. 27B) and *Casurina* etc. In *Opuntia* (*vern.* Chittarthor) the stem is green and leaf-like. It is flattened, fleshy, thick, jointed structure which appears in the axil of caducous leaf on node. This phylloclade shows raised areas called **areoles**. On areoles one or two long spines and stiffened fine **hair bristles** or **glochidia** are present. The spines are modified leaves of suppressed axillary branch. The stem-like nature of phylloclade can be confirmed by : (a) axillary position (b) by presence of flowers and fruits on it.

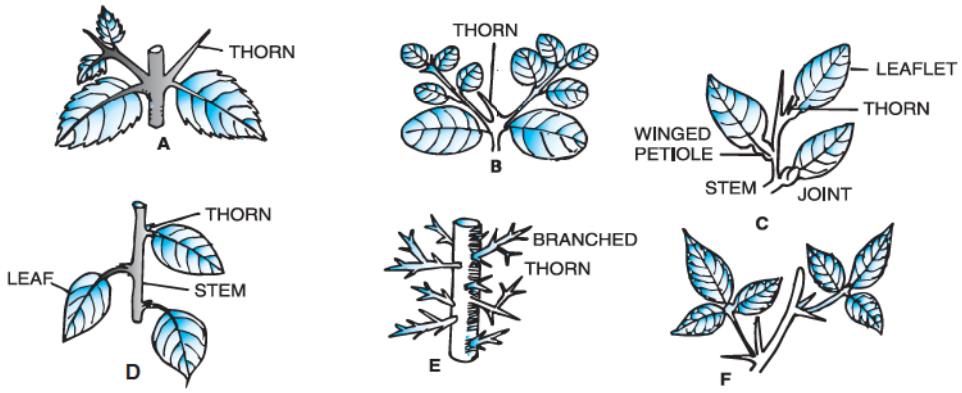


Fig. 26. Stem thorns **A.** *Duranta*; **B.** *Carissa*; **C.** *Citrus;* **D.** *Bougainvillea*; **E.** *Flacourtia* **F.** *Aegle marmelos.*

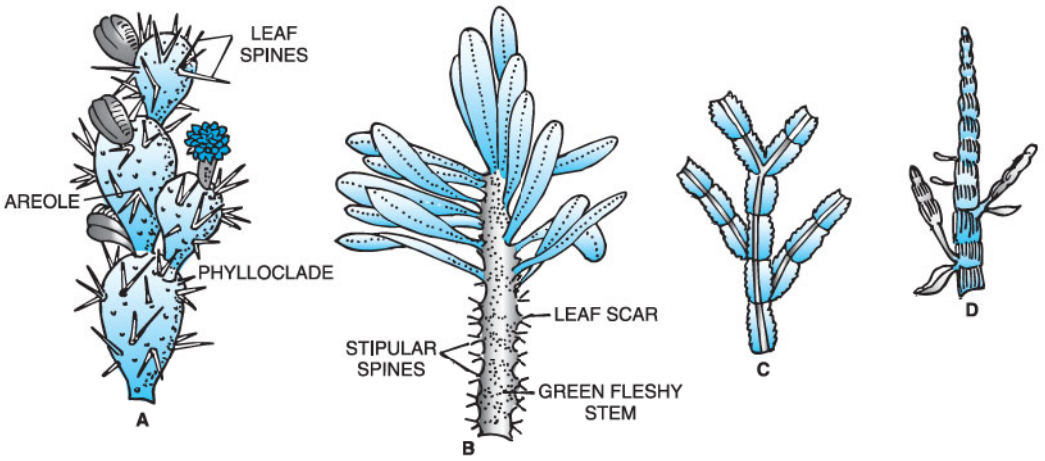


Fig. 27. Phylloclades **A.** *Opuntia*; **B.** *Euphorbia royleana*; **C.** *Epiphyllum*; **D.** Cocoloba (*Muehlenbeckia*).

4. Cladode. Phylloclade with one or two internodes is called cladode *e.g. Asparagus, Ruscus aculeatus.*

In *Asparagus* (Fig. 28A) cladodes are needle-like, slightly flattened green structures which appear in cluster in the axil of a scaly leaf. Main stem bears leaf spines at its nodes. A scale leaf is found just above the spine. Every branch on main stem bears only scale leaves. In the axil of scale leaves cluster of cladodes appear.

Ruscus (Fig. 28B) is another interesting example of cladode which looks very much like leaf. In this case a cladode develops in the axil of scaly leaf. The stem-like nature of this leaf-like cladode can be confirmed by the presence of scale leaf and floral bud.

5. Bulbil. Bulbil (Fig. 29) is the modification of vegetative or floral bud e.g. *Agave* and *Globba*. It is swollen due to storage of food. It can function as an organ of vegetative propagation *e.g. Dioscorea bulbifera* and *Oxalis*. In *Oxalis*, bulbils are formed at the tip of tuberous roots. In *Agave* and onion (*Allium cepa*), bulbils are found on inflorescence and represent the modified flowers.

Functions of stem

A. Primary or main functions

1. It supports and holds leaves, flowers and fruits.

2. Leaves are borne on stem in such a fashion

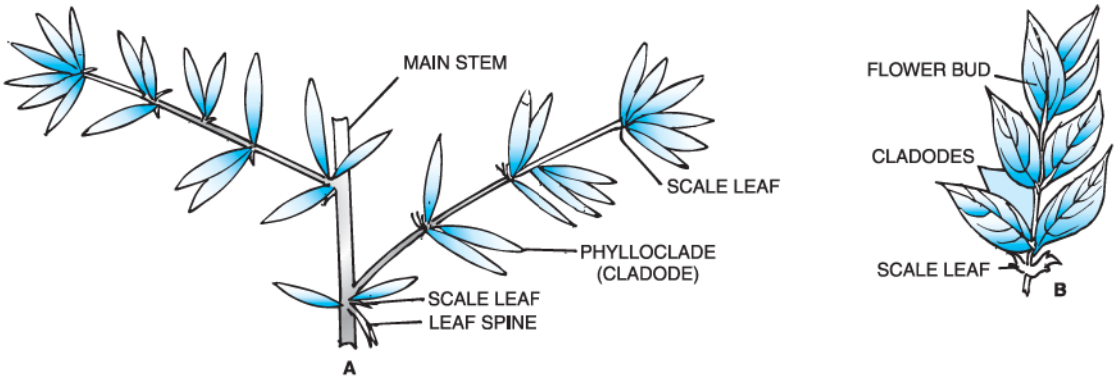


Fig. 28. A. Cladode of *Asparagus*; **B.** Cladode of *Ruscus.*

Table 10. Differences between Phylloclade and Cladode.

Character	Phylloclade	Cladode
1. Modification	Both main axis and its branches get modified into flat, leaf like phylloclades.	Only the branches get modified into leaf like cladodes.
2. Internode	They are usually of unlimited growth and bear many internodes.	Cladodes exhibit the definite or limited growth and are usually with one internode.
3. Leaves	True leaves are caducous in nature.	True leaves are reduced either to scales or modified to form spines.

that they are able to carry on the important function efficiently just like to receive the light and to carry on the gaseous exchange (Fig. 29).

3. The stem conducts the water and minerals from roots to leaves and fruits.

4. Stem bears flowers and fruits in position to facilitate the processes of pollination and fertilization.

B. Secondary or Accessory functions

1. Perennation. The underground stems as in *Dryopteris*, *Zingiber*, *Curcuma* help the plants to tide over the unfavourable conditions.

2. Storage of food. Food is stored in parenchymatous cells and underground stems *e.g. Colocasia*, *Solanum tuberosum* (Potato), ginger etc.

3. Photosynthesis. When modified into phylloclade and cladode *e.g. Opuntia*, *Asparagus* and *Ruscus*, young leaf like flattened stems help in photosynthesis.

4. Vegetative propagation. Stem can be used for vegetative propagation as in case of runners (*e.g.* Grass), stolons (Strawberry), offsets (*Eichhornia*) and underground stems (*e.g.* Potato, Ginger etc.)

5. Protection against browsing. By developing thorns, stem protects the plants from grazing animals.

6. As climbers. The stems may be modified into tendrils, hooks, thorns etc. to climb *e.g. Passiflora*, *Bougainvillea* and *Vitis vinifera*.

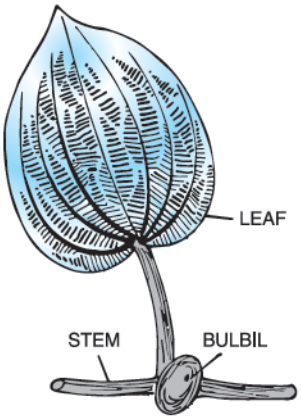


Fig. 29. Bulbil.

LEAF

Leaves are the food manufacturing organs of the plant. All food used by living organisms of all kinds (except few species of bacteria) are products of leaves and other green parts.

Leaves are most important appendages of aerial plants. A leaf is a lateral flattened, green structure borne on a node. Though occasionally they are needle-like or scale-like as in pines and junipers. At the top of stem, there is a mass of cells which divide frequently called **shoot meristem.** The cells constituting this region are small, isodiametric and thin walled. Leaves initiate from the shoot meristem as **leaf primordia** and gradually enlarge, as they grow further.

PARTS OF A LEAF

The green food making leaves of plants are termed **foliage leaves**. A typical foliage leaf (Fig. 30) consists of leaf stalk or **petiole**, expanded portion at the end of petiole is called **blade** or **lamina**. Leaf base is the lowermost part of leaf by which leaf is attached with node. In some cases leaf base becomes swollen to form

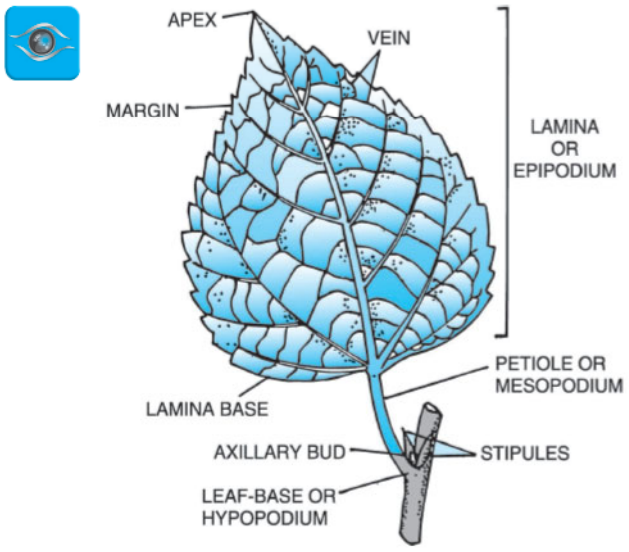


Fig. 30. Parts of a leaf.

ADDITIONAL USEFUL INFORMATIONS ABOUT STEM FOR COMPETITIVE EXAMINATIONS

- *Suckers developing in **Musa** are known as **Sword suckers.***
- *A plant with reduced stem or without a stem is called **acaulescent.***
- ***Cyanodon** (doob grass) is a evergreen herb (perennial).*
- ***Sobole** is underground runner of **Andropygon** and **Saccharum spontaneum.***
- ***Ulex** bears both stem thorns and leaf spines.*
- *Only first internode is tuberous in **Bulbophyllum.***
- *Whole stem is tuberous in knol-kohl.*
- ***Pseudobulb** is thickened part of aerial stem (one or few internodes) in orchids and modified for storing water and other reserves.*
- *Woody climber or twiner is called **liana.***

pulvinus(*Cassia*). Pulvinus is responsible for sleep movements in *Mimosa pudica* (Touch-me-not). In some species of plants leaf base forms small green appendage called **stipule** at the points of juncture of petiole with stem. Stipules probably protect the leaves in young stage.

A leaf with stipules is called **stipulate** and without stipules, **ex-stipulate.** Some leaves lack petioles, their blades growing directly from the stem a condition described as **sessile**. A leaf with petiole is called **petiolate.** Petioles conduct water and solutes from the stems into leaf blades and transport food manufactured in lamina or blade downward into the stem. They expose the lamina to sunlight for photosynthesis.

Lamina in most of plants is flat, thin and broad with conspicuous system of veins and veinlets forming the external framework of lamina or blade. Lamina is usually traversed by a prominent vein in the middle called as **midrib**. Veins contain the vascular tissue and act as channel for the transport of food, water and minerals. They also function as **skeleton** of lamina. The entire network constituted by midrib, veins and veinlets in leaf blade is called **venation**. The side of lamina forms the margin and tip forms the leaf apex. The functions of leaf are :

1. It forms the food by the process of **photosynthesis**.
2. It helps in **gaseous exchange** during respiration.
3. Water loss occurs through stomata in leaves by **transpiration**.

VENATION

The arrangement and distribution of veins and veinlets in the leaf lamina is called venation. Veins in addition to forming the structural framework of blades, are the ultimate branches of the conducting channels which pass into leaves from vascular tissue of stem. Thus veins in the leaves are made up of conducting tissue *i.e.*, xylem and phloem.

There are three main types of venation :

1. Reticulate 2. Parallel 3. Furcate

1. Reticulate venation. When the veins are irregularly distributed to form a network, it is known as reticulate venation. It is a characteristic feature of the dicotyledons. It is of following types:

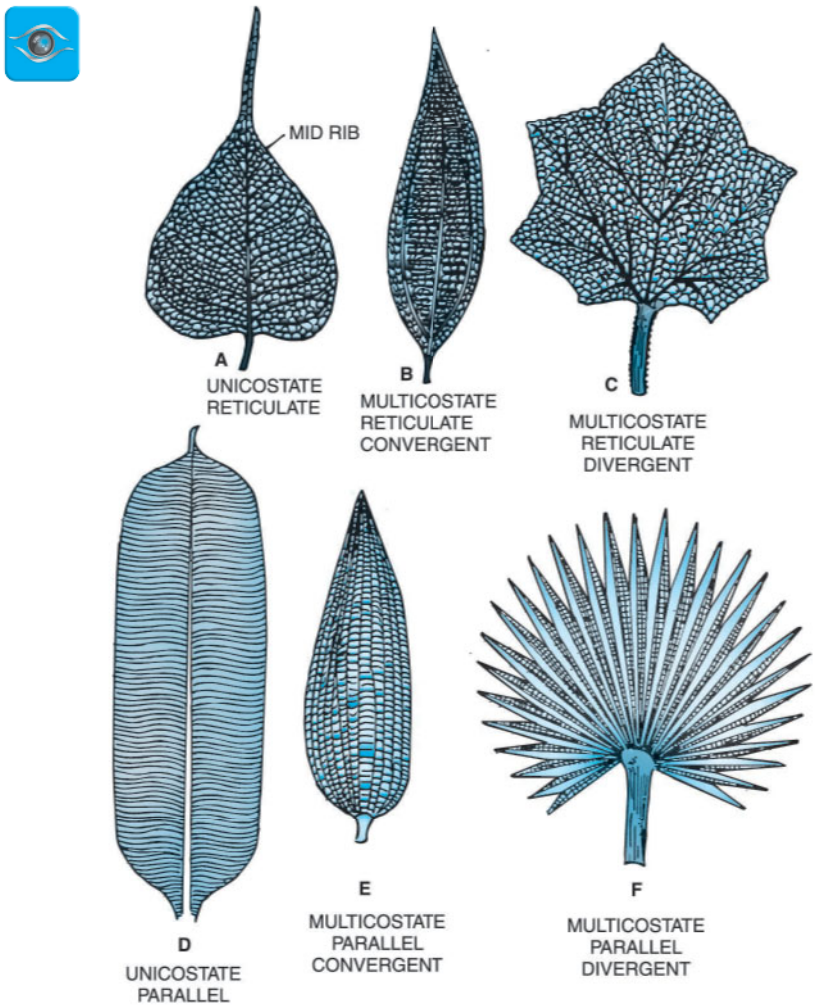
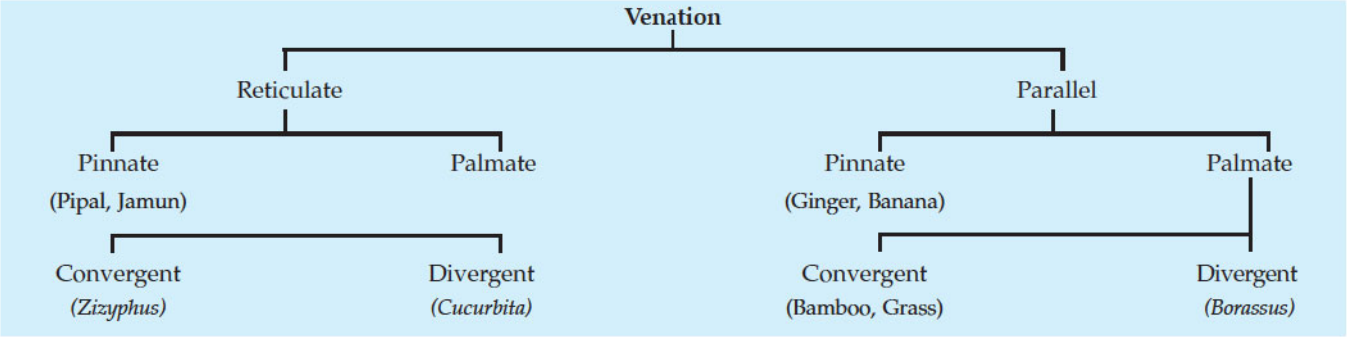


Fig. 31. Venation in leaves.



(a) Unicostate reticulate (Pinnate reticulate). A leaf with a single main midrib or costa is called unicostate reticulate. *e.g. Eugenia* (Jamun), Oleander (Kaner), *Ficus religiosa* (Peepal) (Fig. 31A), *Hibiscus* and *Mangifera* (Mango).

(b) Multicostate reticulate (Palmate reticulate). When there are two or more costae or principal veins arising from a single point. It is of two types :

(i) Multicostate convergent. Many principal veins curved in a curved manner from the base of blade to its apex *e.g. Zizyphus* (Beri) (Fig. 31B).

(ii) Multicostate divergent. Principal or main veins are at the base of leaf and then diverge from one another towards the margin of leaf *e.g. Cucurbita* (Fig. 31C), *Luffa* and *Carica papaya* (Papita).

2. Parallel venation. When the veins are parallel and do not form a network, such a venation is called parallel. It is of two kinds :

(a) Unicostate parallel (Pinnate parallel). The lamina has a single prominent midrib and from this arise lateral veins which run towards the margin *e.g.* Banana (Fig. 31D), Turmeric and *Canna*.

(b) Multicostate parallel venation (Palmate parallel). In this case several veins run parallel to one another.

It can be classified into two types :

(i) Multicostate convergent. The principal veins appear from the base of lamina and converge at apex *e.g. Bambusa* (Bamboo) (Fig. 31E), grasses.

(ii) Multicostate divergent. The main veins appear from the base of lamina towards the margins *e.g. Borassus flabellifer* (Fan palm) (Fig. 31F).

3. Furcate venation. Such types of venation is present in ferns. In such cases veins divide dichotomously (Fig. 31G). The finer branches do not meet to form a reticulum or network.

Exceptions. There are few exceptions to above mentioned examples *e.g.* Monocotyledons like *Dioscorea*, *Smilax* show reticulate venation and *Calophyllum* (Dicotyledon) exhibits parallel venation.

TYPES OF LEAVES

Depending upon the indentation or incision of lamina, the leaves are of two types :

1. Simple leaf

2. Compound leaf.

1. Simple Leaf. A simple leaf can be defined as one in which there is a single lamina, and which is not divided completely into distinct leaflets.

Or

A leaf is said to be simple when its lamina is entire or is incised but the incisions do not touch the mid-rib in pinnate leaf or do not reach up to the tip of petiole in palmate leaf.

The incision is called **pinnate** type when incision takes place from margin towards mid-rib in a unicostate or pinnate lamina. The indentation or incision is called **palmate** type when indentation occurs from margin towards base in palmate or multicostate lamina. Incisions (Fig. 32) are of following types :

(1) Fid. When the incision of the margin is half way **(a) Pinnatifid** *e.g. Chrysanthemum* **(b) Palmatifid** *e.g. Luffa.*

(2) Partite. When the incision is more than half way. **(a) Pinnatipartite** *e.g. Argemone*, *Raphanus* (Radish) **(b) Palmatipartite** *e.g. Ricinus communis* (Castor).

2. Compound Leaves (Pinnate and palmate)

A leaf is called compound when incision of leaf lamina goes down to the mid-rib (rachis) or to the petiole so the leaf is broken up into number of segments called leaflets. In compound leaves the leaflets are distinct. Leaflets remain free from one another and jointed to rachis or tip of petiole.

(a) Pinnate compound leaves

(b) Palmate compound leaves

(a) Pinnate compound leaves. In pinnately compound leaf, mid-rib (rachis) bears laterally a number of leaflets arranged alternately or in opposite manner. It is derived from simple pinnate leaf. Pinnate compound leaf may be of following types :

(i) Unipinnate. In such cases leaf lamina divides only once. Leaflets or pinnae are attached to central axis or rachis which is continuation of petiole. It is further of two kinds :

Paripinnate. When the leaflets are even in number *e.g. Cassia*, *Abrus*, *Sesbania* (Fig. 33A).

Imparipinnate. When the leaflets are odd in number *e.g. Rosa indica* (Rose) (Fig. 33 B), *Azadirachta* (Margosa, Neem), *Murraya* (Chinese box).

(ii) Bipinnate. In such case pinnate leaf divides twice. The leaflets in bipinnate leaf are called pinnules. The pinnules are borne on secondary axis called **rachilla** or **rachule** *e.g. Caesalpinia* (Gold mohur) (Fig. 33C), *Acacia* (Gum tree), *Mimosa pudica* (Touch-me-not), *Albizzia.*

(iii) Tripinnate. When the leaf is divided thrice in a pinnate fashion *i.e.* the secondary axes produce tertiary axes, on which the leaflets are borne. In other words rechillae are further divided to form branches of third order and leaflets in this case are called **Pinnulules** *e.g. Moringa* (Soanjana) (Fig. 33D), *Oroxylon* (Arlu).

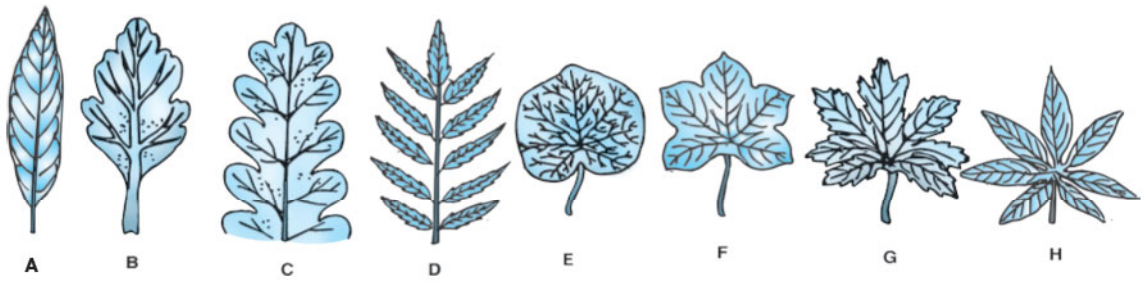


Fig. 32. Incisions of lamina. **A.** Entire pinnate leaf of mango **B.** Pinnatifed of *Chrysanthermum;* **C.** Pinnatipartite of *Launaea;* **D.** Pinnatisect of *Tagetes;* **E.** Entire Palmate leaf of Garden Nasturtium; **F.** Palmatifid of *Luffa;* **G.** Palmatipartite of Castor; **H.** Palmatisect of *Cannabis.*

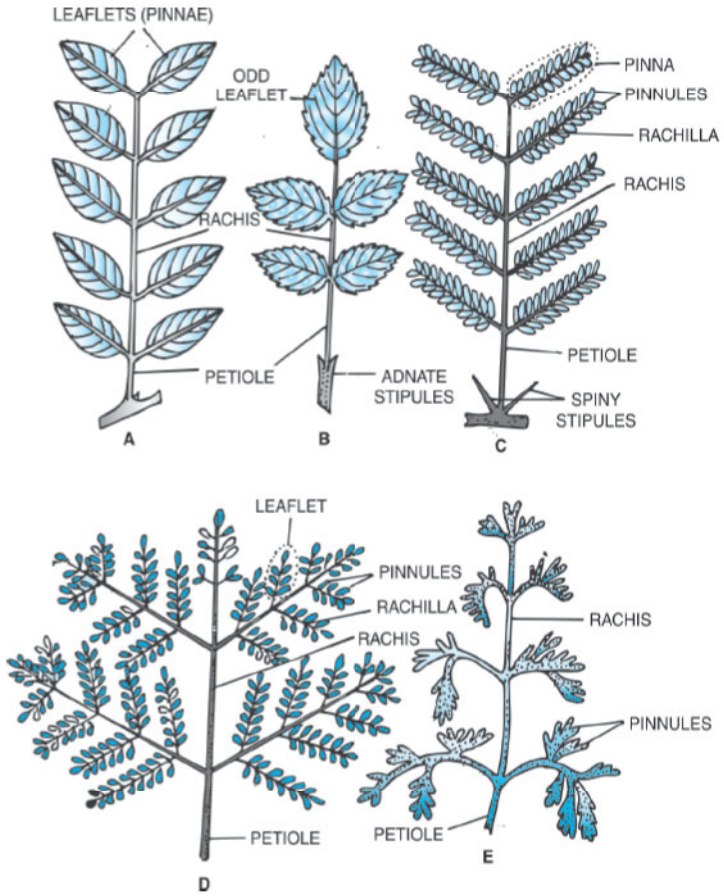


Fig. 33 Compound leaves. **A.** Paripinnate leaf in *Cassia;* **B.** Imparipinnate leaf in Rose; **C.** Bipinnate leaf in *Acacia*; **D.** Tripinnate leaf in *Moringa* and **E.** Decompound leaf in Coriander.

(iv) Decompound. When a compound leaf is more than thrice pinnate *e.g. Coriandrum* (Fig. 33E).

(b) Palmate compound leaves. In palmate compound leaf, leaflets are borne at the tip of petiole like the fingers of palm. It may be :

(i) Unifoliate. In unifoliate type of palmate compound leaf a single leaflet is separated from the petiole by constriction *e.g. Citrus* (Fig. 34). The leaf of *Citrus* looks like a simple leaf, however, its compound nature can be confirmed due to (i) presence of joint between lamina and petiole (ii) by many abnormal leaves, where two leaflets along with central one make their presence. So the *Citrus* is basically trifoliate compound leaf but due to suppression of two lateral leaflets, it has become unifoliate.

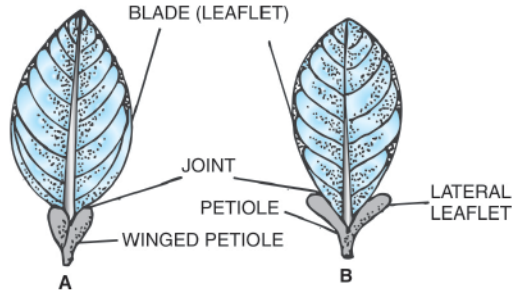


Fig. 34. *Citrus* leaf (Unifoliate compound leaf).
A. Normal; **B.** Abnormal with two lateral leaflets.

(ii) Bifoliate. Two leaflets are jointed to the petiole *e.g. Hardwickia* (Fig. 35A), *Prinsepia*.

(iii) Trifoliate. Three leaflets are articulated to the petiole *e.g. Aegle, Medicago, Oxalis, Trigonella* (Methi) (Fig. 35 B).

(iv) Quadrifoliate. Four leaflets are attached at the tip of petiole *e.g. Marsilea* (Fig. 35C), *Paris quadrifolia* and *Oxalis tetraphylla*.

(v) Multifoliate. Five or more leaflets are articulated to the tip of petiole and spread like fingers of a palm *e.g. Bombax* (Fig. 35D) and *Cleome*.

PHYLLOTAXY

The arrangement of leaves on a stem or branch is called **phyllotaxy.** Phyllotaxy can be defined as **mode of distribution of leaves on stem.** The aim of phyllotaxy is to orient the leaves in such a way that they receive maximum sunlight to perform the function of photosynthesis. It is of three main types :

1. Alternate or Spiral (Fig. 36A). When there is only one leaf borne at each node, the arrangement is called spiral or alternate or acyclic *e.g. Hibiscus* (China rose), *Nicotiana* (Tobacco), *Ficus religiosa* (Peepal). Leaves are usually arranged spirally around the stem. The number of vertical rows in which leaves are arrranged is called as **orthostichies**.

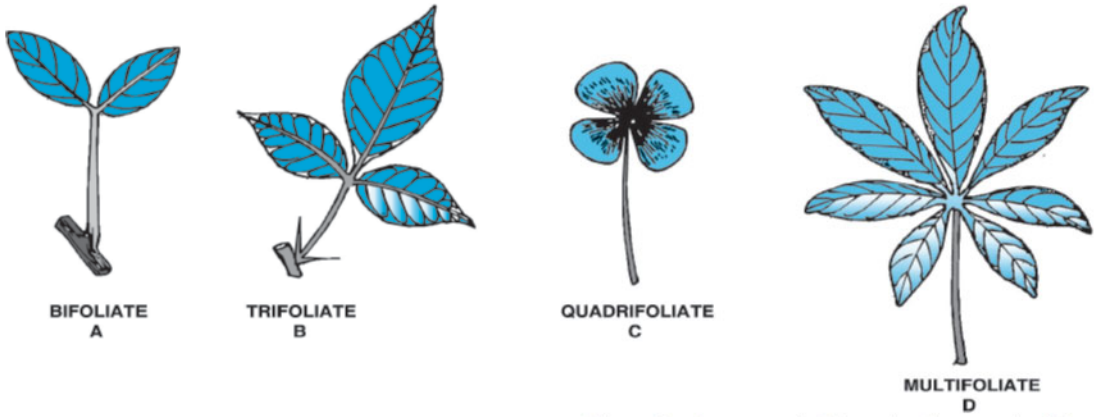


Fig. 35. Palmate compound leaves. **A.** Bifoliate leaf; **B.** Trifoliate leaf; **C.** Quadrifoliate leaf; **D.** Multifoliate leaf.

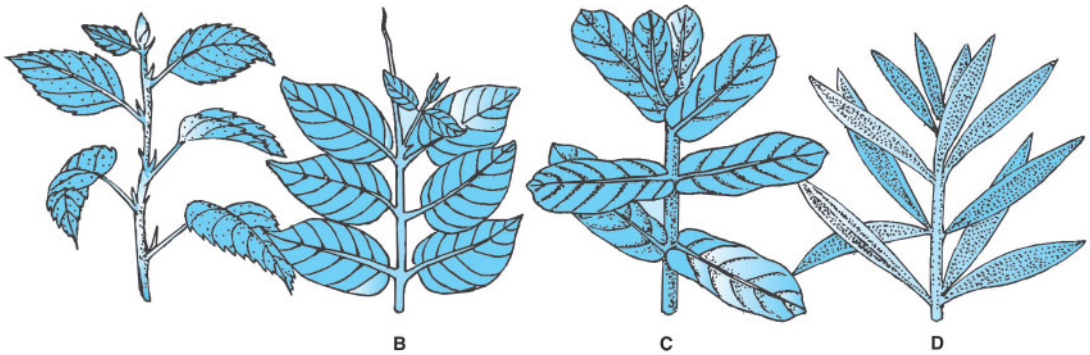


Fig. 36. Phyllotaxy **A.** Alternate or spiral; **B.** Opposite and superposed in *Quisqualis*; **C.** Opposite and decussate in *Calotropis*; **D.** Whorled in *Nerium*.

2. Opposite. In opposite phyllotaxy two leaves appear at each node and lie always opposite to each other. It is further of two types :

(a) Opposite and Superposed. When the opposite leaves of two adjacent nodes are in the same direction *i.e.* two opposite leaves of one node lie exactly below those of the upper node and above those of the lower node in the same plane, the phyllotaxy is called as opposite and superposed, e.g *Eugenia* (Jamun), *Quisqualis* (Rangoon creeper) (Fig. 36B)

(b) Opposite and decussate. In this type of phyllotaxy the leaves of successive nodes are placed at right angle to each other and thus the leaves get arranged in four vertical rows *e.g. Calotropis* (Ak) (Fig. 36C), *Ocimum* (Tulsi) and *Zinnia*.

(c) Whorled. When three or more leaves are present at node, phyllotaxy is known as whorled or verticillate. They are borne in whorl or circle *e.g. Nerium* (Oleander, vern. kaner) (Fig. 36D), *Alstonia*, *Galium*.

LEAVES WITH DIFFERENT FUNCTIONS OR MODIFICATIONS OF LEAVES

The leaf or part of leaf is occasionally modified into other structure. They can perform special functions other than photosynthesis. Prominent examples are :

1. Leaf tendrils. Tendrils are thread-like green structures, which are sensitive to touch and are capable of coiling around the support. They can be differentiated from stem tendrils by absence of scaly leaves over them and being unbranched. Following are the examples of leaf tendril :

(a) Whole leaf tendril. In *Lathyrus aphaca* (Wild pea) (Fig. 37A), the whole leaf is modified into tendril. Stipules in this case become large and foliaceous and carry out the function of photosynthesis.

(b) Leaflet tendril. In *Pisum sativum* (Sweet pea) and *Lathyrus odoratus* (Garden pea) upper leaflets of compound leaf are modified into tendrils. The lower leaflets remain unchanged (Fig. 37 B).

(c) Stipular tendril. Stipular tendrils are found in *Smilax* (Fig. 37E).

Table 11. Differences between Simple and Compound leaf.

Character	Simple leaf	Compound leaf
1. Incision	The lamina is not divided into distinct lobes or leaflets *i.e.* it has single lamina.	The lamina is incised into two or more distinct leaflets. The leaflets are borne either at the tip of petioles or on the sides of rachis.
2. Axillary bud	An axillary bud is present in the axil of simple leaf.	Individual leaflets do not bear any axillary bud. However, bud is present in the axil of whole leaf.
3. Arrangement	Simple leaves appear in acropetal succession on stem.	Leaflets of a compound leaf do not appear in acropetal succession on rachis.
4. Stipules	The base of leaf may bear stipules.	Stipules may be present at the base of compound leaf however such structures are never present at the base of leaflets.
5. Plane	Simple leaves may appear in one or more planes.	Leaflets in a compound leaf appear in one plane only.

Table 12. Differences between Pinnate compound leaf and Palmate compound leaf.

Character	Pinnate compound leaf	Palmate compound Leaf
1. Shape	Feather like.	Like palm of hand.
2. Origin of leaflets	Leaflets appear on elongted axis.	Leaflets appear from common point.
3. Appearance	Leaflets appear in two rows.	Leaflets are clustered together.
4. Joint	Joint absent between leaflet and its axis.	Joint is usually present between leaflet and point of attachment.
5. Origin	Axis bearing leaflets is continuation of branch of mid-rib.	Tip of petiole represents the leaflet bearing point.

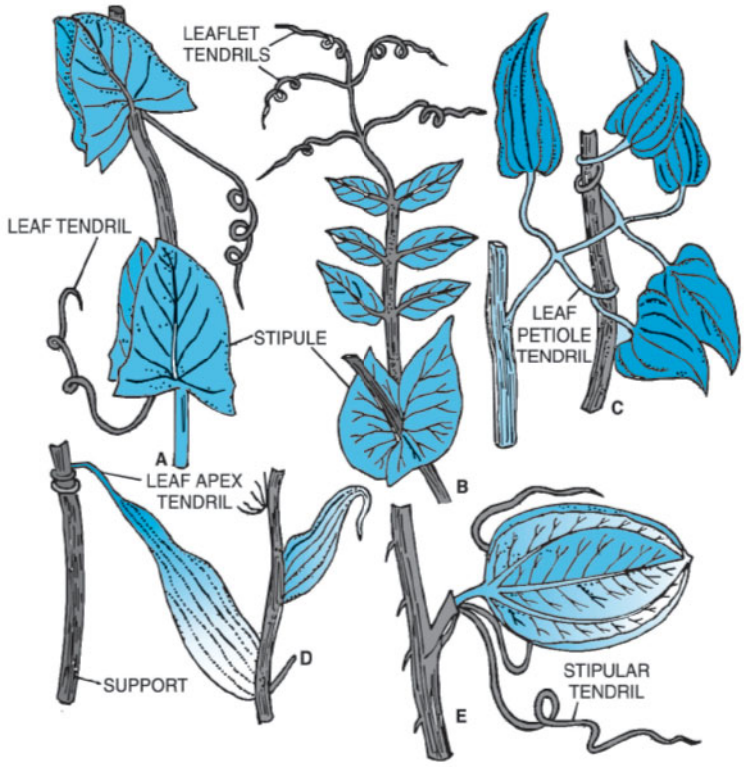


Fig. 37. A. Whole leaf tendril in *Lathyrus aphaca*; **B.** Leaflet tendril in *Pisum sativum*; **C.** Rachis tendril in *Clematis*; **D.** Leaf tip tendril in *Gloriosa* and **E.** Stipular tendril in *Smilax*.

(d) Petiolar tendril. The petioles of some plants like *Tropaeolum* (Garden nasturtium), *Naravelia* become tendril-like. The rachis and leaf-stalks of leaflets form tendril in *Clematis* (Fig. 37C).

(e) Leaf apex tendril. In *Gloriosa superba* (Fig. 37 D) leaf apex becomes sensitive and drawn out to form tendril.

2. Leaf spines. In plants like Barberry (Fig. 40A), *Opuntia*, *Aloe* and *Argemone* leaves are modified into spines. Spines protect the plant from grazing animals and also reduce the area for transpiration. The leaf nature of spines can be made out by the presence of buds in their axils.

3. Food storage. Food is stored in the leaves of *Allium cepa* (onion). The leaves may also become fleshy or juicy (succulent) due to storage of water, mucilage and food material *e.g. Aloe* and *Portulaca.*

4. Leaf pitcher. Pitchers are found in epiphytic climber of *Dischidia rafflesiana* (Fig. 38C), which represents the modified leaves. Debris along with rainwater collects in these pitchers and finally water is absorbed by the adventitious roots, which come out of stem nodes and ramify in the pitcher cavities.

In *Nepenthes* or pitcher plant (Fig. 38A, B) pitchers are held vertically by a tendril-like, slender coiled stalk, petiole. The lid of pitcher represents the modified leaf apex. Leaf lamina is modified into pitcher. The flattened basal portion is the leaf base. Pitchers are also formed in *Sarracenia.*

5. Leaf bladder. In insectivorous plants like *Utricularia* (bladder wort), leaves are modified to form bladder. Such plants have mechanism to catch insects and feed on them.

Table 13. Differences between Stem and Leaf tendrils.

Character	Stem tendrils	Leaf tendrils
1. Branching	Stem tendrils are usually branched.	They are usually unbranched.
2. Scaly leaves	Scale leaves may be present in the region of forking.	Scale leaves are not found on the tendrils.
3. Buds	The buds may be present in axis of scaly leaves.	Buds are not present on leaf tendrils.
4. Position	They may appear from stem, bud or flower.	They appear from leaf or its parts.

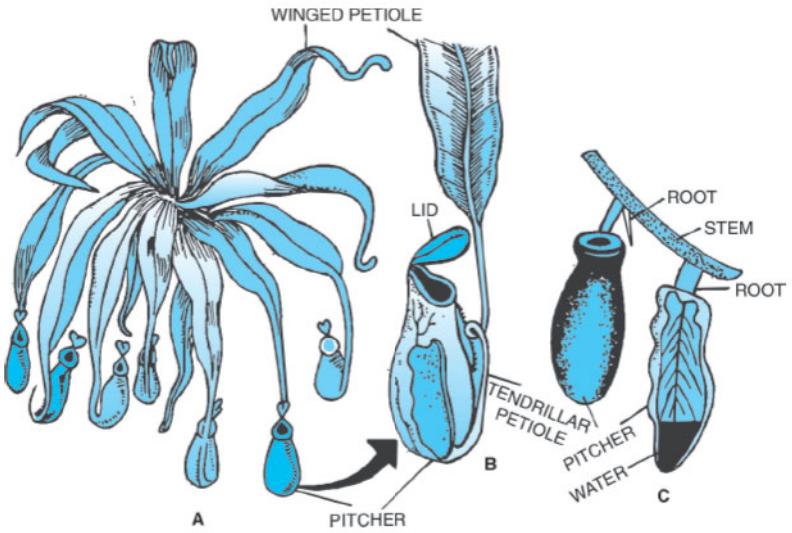


Fig. 38. A. *Nepenthes* plant, **B.** A pitcher enlarged, **C.** *Dischidia.*

6. Phyllode. In case of Australian acacia (*Acacia auriculiformis*) (Fig. 39) the normal leaf is bipinnate compound. The leaflets disappear, petiole get flattened and green in colour to perform the function of photosynthesis. This type of modification when petiole of leaf is modified into lamina or leaf blade-like structure is known as phyllode.

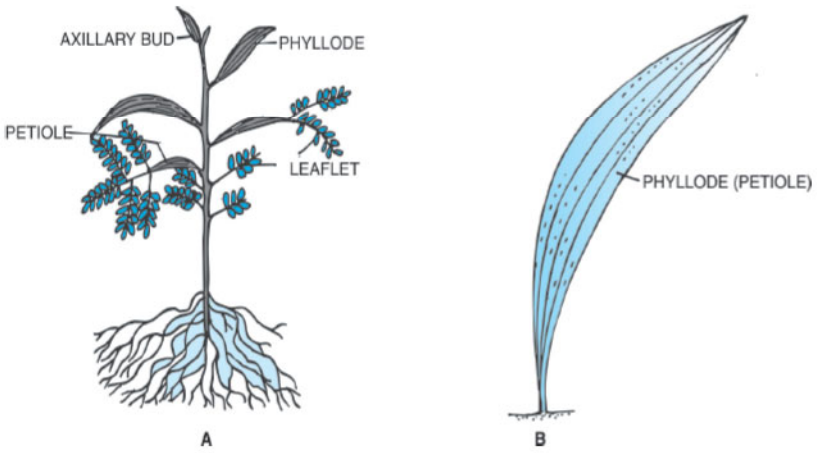


Fig. 39. Phyllode of Australian acacia.
A. A young plant showing transformation of petiole into phyllode; **B.** A phyllode only.

Table 14. Differences between Phylloclade and Phyllode.

Character	Phylloclade	Phyllode
1. Modification	It is the stem modification into leaf-like structure.	It is the petiole modification into leafy structure.
2. Origin	It arises in the axil of a leaf which can fall off and leaves a scar.	Phyllode does not arise in the axil of a leaf because it is itself a leafly structure.
3. Axillary bud	It does not bear any axillary bud.	A bud is present in the axil of a phyllode.
4. Leaves, flowers	Phylloclade can develop leaves and flowers etc.	No such structures are found on phyllode.
5. Peproduction	It helps in vegetative propagation.	It does not help in any type of reproduction.
6. Nodes and internodes	Nodes and internodes are borne on phylloclade.	A phyllode does not bear nodes and internodes.
7. Storage	It stores food and becomes usually fleshy.	It does not store food.
8. Position	It may be vertical or horizontal in position.	It is always vertical in position.

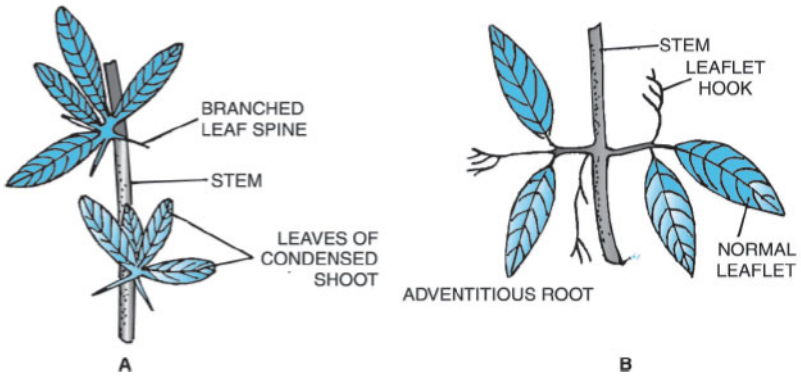


Fig. 40 A. Leaf spines of Barberry; **B.** Leaf hooks in *Bignonia unguis cati.*

7. Leaf hooks. In *Bignonia unguis cati* (Fig. 40 B) three terminal leaflets of compound leaf are modified into claw like hooks which help the plant in climbing.

8. Reproductive leaf. Leaves of *Bryophyllum* and *Begonia* bear adventitious buds on them and help in vegetative propagation of plants.

9. Leaf roots. The leaves are modified into roots in *Salvinia* (water fern). Out of three leaves at each node, one forms roots and the other two remain normal.

10. Heterophylly. The occurrence of different kinds or more than one type of leaves on the same plant is called as heterophylly. In *Ranunculus aquatilis* and *Limnophila heterophylla* submerged leaves differ completely from floating leaves. In *Eucalyptus* and *Sonchus*, the leaves differ in their shape and size which appeared at different developmental periods on the same plant.

FUNCTIONS OF LEAF

A. Primary functions of leaves

1. Photosynthesis. The principal function of the leaves is to manufacture organic food. The seat of photosynthesis are the green cells of leaf having chlorophyll.

2. Transpiration. The loss of water from leaf surface is known as transpiration. It is necessary to create force or tension in water column and thus cause ascent of sap.

3. Gaseous exchange. It takes place in leaves through stomata during the process of photosynthesis and respiration.

B. Secondary functions of leaves

1. Storage of food in leaf bases *e.g.* onion.

2. Water is stored in the leaves of succulent nature (*Bryophyllum* and *Aloe*).

3. Protect the plants from grazing animals when modified into spines (*Opuntia* and *Barberry*).

4. It reduces the rate of transpiration when changed into Phyllode *e.g. Acacia auriculiformis.*

5. They help in climbing the plants having weak stem, when modified into tendrils and hooks.

6. Leaves help the plants in vegetative multiplication (*Bryophyllum*).

7. Leaves act as balancers for floating when modified into roots *e.g. Salvinia.*

8. The leaves are modified into sepals, petals, stamens and carpels to take part in sexual reproduction.

ADDITIONAL USEFUL INFORMATIONS ABOUT LEAF FOR COMPETITIVE EXAMINATIONS

- *Belt's corpuscles are the glands producing edible materials at the apices of leaflets in* ***Acacia sphaerocephala.***
- ***Monophyllea*** *is a plant with single leaf.*
- *The semiamplexicaul or cup-like leaf base protects the axillary bud in* ***Platanus*** *and* ***Robinia.***
- *Petiole is hollow, tubular or fistular in* ***Carica papaya.***
- *Leaf with largest diameter of about 1.8 m. is of* ***Victoria amazonica*** *(Aomazon lily).*
- *Leaf mosaic is characteristic of sciophytes where leaves of various size and shape are crowded forming a mosaic.*
- ***Stipel*** *is stipule like outgrowth at the base of leaflets in sub-family Papilionatae of family Leguminosae.*
- *Longest leaf is of* ***Raphia vinifera*** *(10-15 m.)*
- *In* ***Berberis,*** *whole leaf is modified into spine.*
- *Bamboo is tallest grass. It is also considered as tallest shrub or arborescent grass.*
- *In* ***Quisqualis,*** *the petiole becomes herdened and pointed ater the lemina falls off (spinous petiole)*

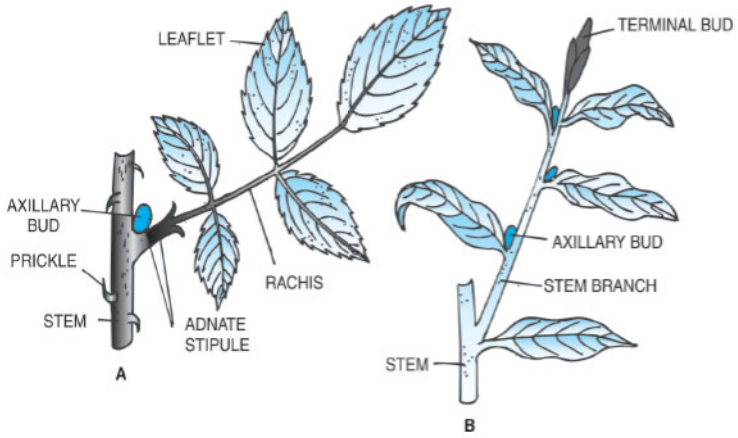


Fig. 41. A. A branch of rose bearing imparipinnate compound leaf; **B.** An axillary branch bearing simple leaves.

Table 15. Differences between Branch bearing simple leaves and a Pinnate compound leaf.

Branch bearing simple leaves	A pinnate compound leaf
1. It arises in the axil of a leaf.	1. It bears a bud in its axil.
2. Terminal or apical bud is always present.	2. The terminal bud is absent and is replaced by one or two leaflets.
3. Buds are present in the axil of simple leaves born on the branch.	3. Buds are absent in the axil of leaflets.
4. During leaffall, branches usually do not fall, only leaves fall.	4. During leaf fall, the entire leaf including leaf lets and rachis falls down.
5. The leaves on a branch may appear in different planes.	5. Leaflets of a pinnate compound leaf appear and lie in the same plane.
6. The branch is differentiated into nodes and internodes.	6. The rachis is not differentiated into nodes and internodes.
7. Number of leaves on a branch is unlimited.	7. Number of leaflets in a compound leaf is fixed.
8. Pulvinus is not present at the base of a branch.	8. The leaf base may bear pulvinus *e.g. Cassia.*
9. A branch may bear flowers.	9. A leaf never bears flowers.
10. At the base of branch, stipules are absent. However, leaves may be stipulated.	10. Stipules may be present at the base of whole leaf but always absent at the base of leaflets.

ADDITIONAL USEFUL INFORMATIONS ABOUT MORPHOLOGY OF PLANTS FOR COMPETITIVE EXAMINATIONS

- *A plant having normal root system initially but later becoming epiphyte is called **hemi-epiphyte.** A plant with normal root system initially but later becoming unconnecting climbing epiphyte e.g. Monstera, Scindapsus is called **pseudo-epiphyte.***
- ***Wolffia** (less than 0.1 mm) is smallest angiosperm.*
- ***Eucalyptus regnans** is the **tallest** plant with height of more than 114 m. (375 ft.)*
- *A gymnosperm **Sequoia semprvirens** (red wood tree) is most **massive** plant which is over 111 m. tall and more than 24 m. in girth.*
- ***Zostera** is a marine angiosperm.*
- ***Pingnicula** (butterwort) bears rosette of fleshy yellow leaves having mucilage and digestive glands and is capable of curling to trap small animals.*
- ***Aldrovanda** (water flea trap) is rootless free floating aquatic with leaves similar to **Dionoea** for trapping small animals.*
- *The characteristic foul odgour of onion is due to an oil like organic compound of **sulphur allyl sulphide** formed in fleshy leaves.*
- *Antidiabetic effect of garlic is due to the presence of sulphur containing amino acid S–allyl cystine sulphoxide (SACS).*

PRACTICE PROBLEMS – MORPHOLOGY OF PLANTS

1. A root system is extensively branched and bears a very large number of delicate root tips. How do the root tips manage to penetrate the hard core of soil?
2. Define buds, nodes and internodes. What is the difference between the axillary bud and terminal bud?
3. How do the buds protect themselves?

4. Supply the appropriate scientific term for each of the following :
   - **A.** Root developing from any part of the plant other than the radicle.
   - **B.** Shapeless swollen root occurring singly.
   - **C.** Pillar like roots appearing from large horizontal branches.
   - **D.** Naked flowering stem arising from ground without leaves.
   - **E.** Leaf with single lamina and which is not completely divided to form leaflets.
   - **F.** Underground stem growing vertically, rarely branched and spherical or oval in form.
   - **G.** Runner with short internodes and each node bearing a rosette of leaves and tuft of roots.
   - **H.** Roots are swollen, become spindle shaped and found singly.
   - **I.** Veins irregularly distributed in the lamina forming a network.
   - **J.** The arrangement of the leaves on the stem.
5. Differentiate between herbaceous and woody stems.

ANSWERS TO PRACTICE PROBLEMS

1. The cells of root cap secrete a mucilaginous substance that acts as a lubricant. It facilitates the tender root tips to enter the hard crust of the soil.
   Root cap is composed of parenchymatous cells and these cells store the starch. The starch grains are responsible for geotropism.
2. **Buds.** The bud is a small compact structure and the shoot develops from it. Plumule is the first bud.
   Node. It may be defined as a point of attachment for a leaf on the stem.
   Internode. The interval between two adjacent nodes is called internode.
   Axillary bud. The buds which are located in the axil of each leaf are called axillary or lateral buds. These buds grow into branches.
   Terminal bud. The bud which remains at the rip and continue to grow indefinitely, is called terminal or apical bud.
3. **1. Bud scales.** The buds are covered by dry scaly outer leaves called bud scales e.g. *Ficus, Magnolia.*
   2. Hair. Dense mass of hair is present around bud *e.g. Zizyphus.*
   3. Folded leaves. The leaves of buds are very compact and folded to protect themselves.
   4. Resinous secretions. In some plants the buds are covered by wax, cutin, resinous secretions to prevent their wetting and also to check transpiration.
4. **A.** Adventitious root **B.** Tuberous root **C.** Prop roots **D.** Scape
   E. Simple leaf **F.** Corm **G.** Offset
   H. Tubercular roots **I.** Reticulate venation **J.** Phyllotaxy.
5.

Herbaceous stem	Woody stem
1. They are annual or biennial and short lived.	1. They are always perennial and long lived.
2. They are green, soft and fleshy and on bending does not break.	2. They are brown or grey and hard and break on bending.
3. The protective superficial layer is epidermis.	3. The epidermis is replaced by corky-layer or bark.
4. They contain stomata for gaseous exchange.	4. They develop dot-like pores, the lenticels for gaseous exchange.
5. Buds are often naked.	5. Buds are often protected by scales.
6. They mainly consist of primary permanent tissue.	6. They mainly consist of secondary permanent tissue

INFLORESCENCE

The flowers are arranged in some definite manner on the plant in each species of the flowering plants. **The mode of arrangement of flowers on a specialised branch on top of the plant which bears flowers is called inflorescence.** The axis of the inflorescence is called **peduncle**. Sometimes the flowers are borne singly. Such arrangement is said to be **solitary.** When solitary flowers are borne at the tips of branches or main stem, they are described as **Solitary terminal** *e.g.* Poppy or they may be borne in the axil of a foliage leaf and are termed as **Solitary axillary** *e.g. Petunia*, Garden Nasturtium and *Hibiscus rosa-sinensis* (China rose) (Fig. 42).

Like branching inflorescence also may be **racemose** or **cymose**. It may also be **mixed** type when it is partly racemose and partly cymose. Depending upon the growth, form of peduncle and arrangement of flowers, **special** inflorescence are also formed.

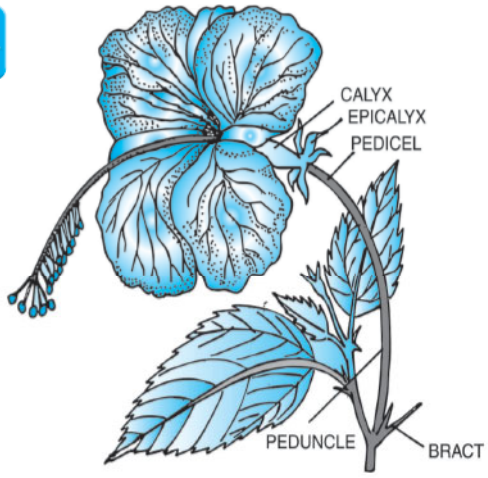


Fig. 42. Solitary axillary flower of *Hibiscus rosa-sinensis.*

1. Racemose or indefinite inflorescence

The peduncle grows indefinitely and bears flowers in **acropetal order** *i.e.* older ones at the base and younger flowers near the apex or growing point. Sometimes the peduncle instead of developing into long axis, condenses to form a flat rounded structure called receptacle. In this case arrangement of flowers become **centripetal** *i.e.* younger flowers are found in the centre of the inflorescence. In **simple racemose** type of inflorescence the peduncle remains unbranched. Racemose inflorescences are classified as under :

(a) Flower stalked

Raceme. When the pedicellate (stalked) flowers are borne acropetally on an elongated axis *e.g. Raphanus*, *Crotolaria* (Fig. 43 A), *Delphinium* (Larkspur), *Lupinus* (Lupin) etc.

(b) Flower sessile

(i) Spike. Inflorescence is similar to **raceme** bu the flowers are sessile *e.g. Achyranthes aspera*, *Callistemon* (Bottle brush), *Antirrhinum* (Dog Flower), *Piper longum* (Long pepper) (Fig. 43 B) *Adhatoda* and *Amaranthus*.

(ii) Catkin or Amentum. A catkin is a spike in which the axis is thin and weak. Flowers are sessile and borne in acropetal order as in spikes. The catkin is mostly pendulous and flowers are unisexual. They drop off as a whole, when they mature *e.g. Salix* (Willow), *Morus* (Mulberry), *Populas* (Poplar), *Acalypha*, *Croton* (Fig. 43 C) and *Betula*.

(iii) Spadix. It is a modification of spike having thick and fleshy peduncle, which may be variously coloured on the upper side. The flowers are covered by one or more **spathy bracts.** The flowers are small, inconspicuous and unisexual. The lower flowers on peduncle are usually female and upper are male. Male and female flowers are separated by sterile hairs or neuter flowers. Spathe may be brightly coloured, spotted or green. The upper sterile, attractive part of peduncle is called **appendix** *e.g. Colocasia* (Arum), *Amorphophallus titanum*, Banana etc. (Fig. 44 A,B).

(iv) Spikelet. It is a type of very small spike with one or few florets. Spikalets are arranged in spite, raceme or panicle fashion. Each spikelet bears at its base two minute bracts called **empty glumes.** Little above, third bract known as **flowering glume** or **fertile glume** or **lemma** or **lower palea** is present opposite the lemma

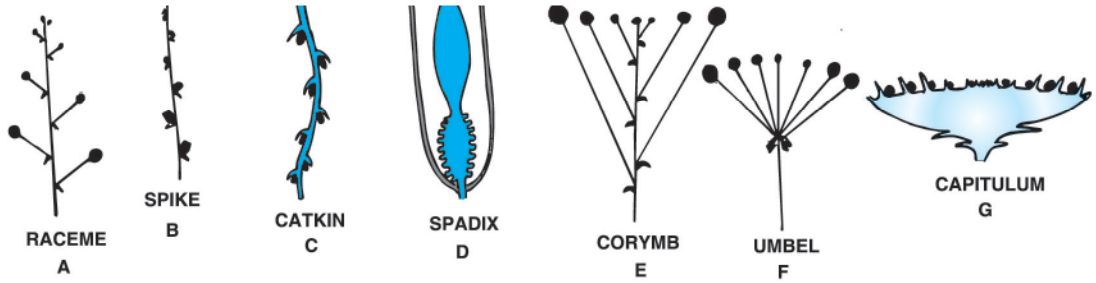


Fig. 43. Types of racemose inflorescence.

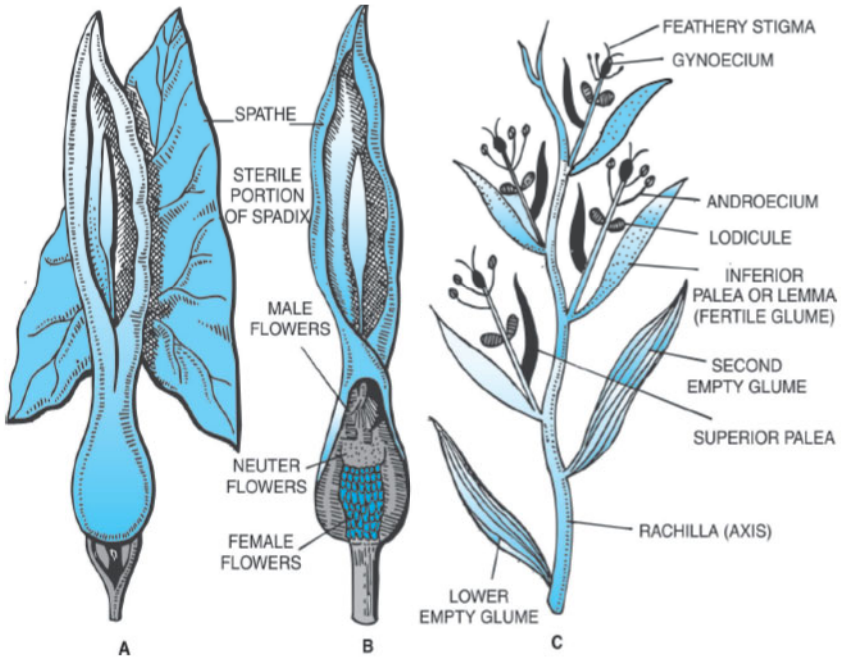


Fig. 44. A. and **B.** Spadix of *Colocasia antiquorum*, **C.** Spikelets of wheat.

it bears the small glume called **upper palea.** Every floret of spikelet remains enclosed by a lemma and palea *e.g.* Wheat, rice, oat, bamboo, sugarcane. (Family–Gramineae) (Fig. 44 C).

(c) Peduncle shortened

(i) Corymb. In Corymb peduncle is shortened. Pedicellate flowers borne at different points reach at the same level. The pedicels of lower, older flowers are longer and those of upper, younger flowers are shorter *e.g. Iberis amara* (Candytuft) (Fig. 43 E, 45) and cherry.

(ii) Corymbose raceme. The young flowers appear to be arranged like corymb but in mature state the longer pedicels of the lower flowers do not bring them to the level of upper ones *e.g.* mustard.

(d) Peduncle suppressed

Umbel. In umbel peduncle is reduced to a point. Pedicellate flowers appear in cluster. The youngest flower in the centre and older ones are towards periphery (**centripetal order**). Number of bracts in the form of involucre are borne at the base of flowers *e.g. Hydrocotyle asiatica.* When the axis of umbel branches, one gets a compound umbel *e.g. Foeniculum* (Fennel), *Coriandrum* (Coriander), *Daucus carota* (Carrot) etc. (Fig. 43F, 47 A–B).

(e) Peduncle flattened to form receptacle

Capitulum. This is the characteristic inflorescence of family compositae. The peduncle forms a flattened more or less convex receptacle, on which very small sessile flowers called florets are arranged in a centripetal order. The florets present at the centre of receptacle are termed as **disc florets** while peripheral florets are known as **ray florets**. The whole capitulum is surrounded by an **involucre** or **bracts**. When disc and ray florets are alike in their sex and symmetry the inflorescence is described as **homogamous capitulum** *e.g. Ageratum* and *Sonchus.* If the disc and ray florets differ in their sex and symmetry the inflorescence is termed as **heterogamous capitulum** *e.g. Helianthus annus* (Sunflower) (Fig. 46), Marigold and *Zinnia.*

2. Cymose or definite inflorescence

In this case the main axis stops its growth and terminates into a flower. The lateral branches appear below it, which also terminate into flowers. The central flower opens first. The opening of flowers is **basipetalous** (towards base). It becomes **centrifugal** when the axis is flattened to form a receptacle.

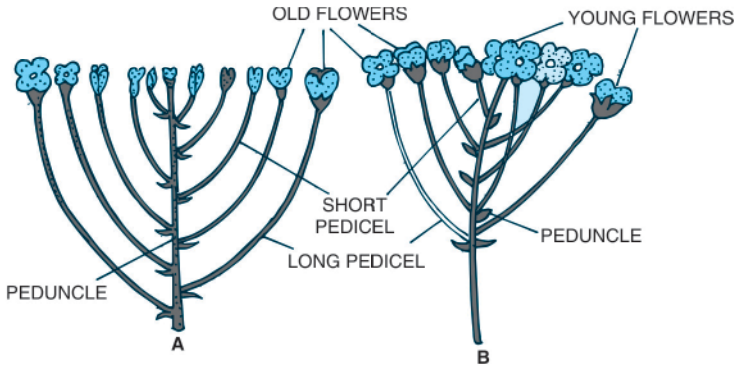


Fig. 45. (A–B). Corymb inflorescence. **A,** corymb (diagrammatic); **B,** corymb of *Iberis* (candytuft).

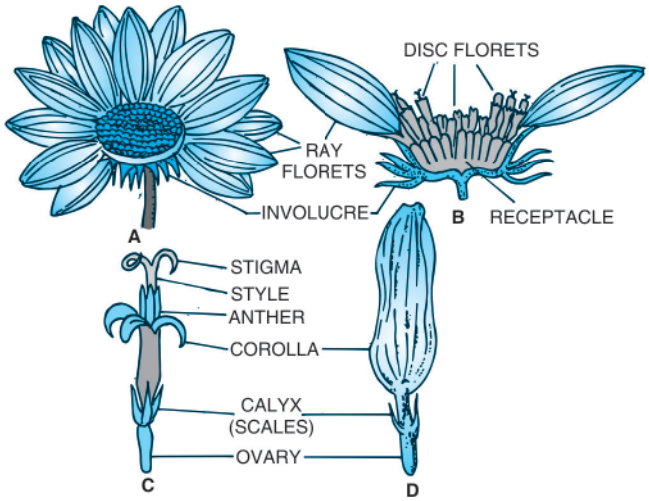


Fig. 46. (A–B) Capitulum or racemose head of *Helianthus annus* : **A.** an entire capitulum **B.** a vertical section of capitulum; **C.** An entire disc floret; **D.** An entire ray floret.

Table 16. Differences between Corymb and Umbel.

Character	Corymb	Umbel
1. Peduncle	Elongated	Reduced to small point.
2. Involucre	Absent	Present
3. Positions of flowers	Flowers are borne at different levels.	Flowers develop from same point.
4. Size of pedicels	Older flowers are with longer pedicels	Pedicels are of similar size.
5. Arrangement of flowers	Acropetal.	Centripetal.

Table 17. Differences between Racemose and Cymose inflorescence.

Character	Racemose inflorescence	Cymose inflorescence
1. Main axis	Elongated with unlimited growth and does not end in a flower.	Short with limited growth and ends in a flower.
2. Arrangement of flowers	Acropetal—*i.e.* youngest near the apex and older at the base.	Basipetal—*i.e.* oldest near the apex and younger at the base.
3. Flower opening	Centripetal.	Centrifugal.
4. Mother axis	Monopodial with true axis.	Sympodial.

Table 18. Differences between Spadix and Capitulum.

Character	Spadix	Capitulum
1. Peduncle	Thick and fleshy.	Shortened to form receptacle.
2. Spathe	Leafy bracts or spathe present.	Bracts form involucre.
3. Florets	Both male and female flowers are separated by sterile portion.	Disc and ray florets are present.
4. Examples	Sunflower, *Sonchus*.	*Colocasia*, banana.

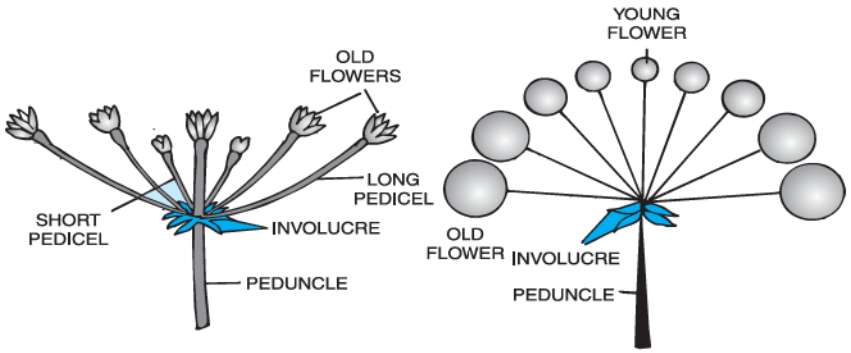


Fig. 47. (A–B) A, an umbel : **B,** an umbel (diagrammatic).

(i) Monochasial or uniparous cyme. In this case main axis terminates in a flower and one lateral branch appears from its base also ending in a flower e.g. *Bigonia*, *Hamelia* and *Drosera* (sun dew). It may be of helicoid or scorpioid type. The peduncle of inflorescence is formed by the fusion of bases of lateral floral branches and called as **sympodial axis**.It is of two types :

(a) Helicoid. The successive lateral branches arise on the same side of the axis forming a helix *e.g. Myosotis palustris* (Fig. 48), *Drosera*.

(b) Scorpioid. The successive lateral branches with their flowers are produced on alternate sides forming a zig-zag structure *e.g. Ranunculus bulbosus* (Fig. 48), *Freesia* and *Tecoma*.

(ii) Dichasial or biparous cyme. In this case also main axis terminates in a flower. Two lateral branches arise from its upper node but they also end in flowers. Each lateral branch acts as main axis and develops two lateral flowers. The oldest flower is in the centre and subsequent younger flowers are lateral in position, thus representing the basipetal or centrifugal order *e.g. Dianthus* (Pink), *Silene* (Takla), *Spergula* (Fig. 48) *Bougainvillea*, teak and jasmine.

(iii) Polychasial or multiparous cyme. In this case more than two lateral branches are produced from the base of the apical flower. Further branching occurs in the same manner *e.g. Calotropis*, *Nerium*, *Viburnum* (Fig. 48) and *Asclepias*.

3. Special types of inflorescence

(a) Hypanthodium. In this case fleshy receptacle forms a hollow cavity which is more or less pear shaped with a narrow apical opening guarded by scales. Canal is lined by downwardly pointed hairs. Internally the receptacle bears male flowers towards the pore and

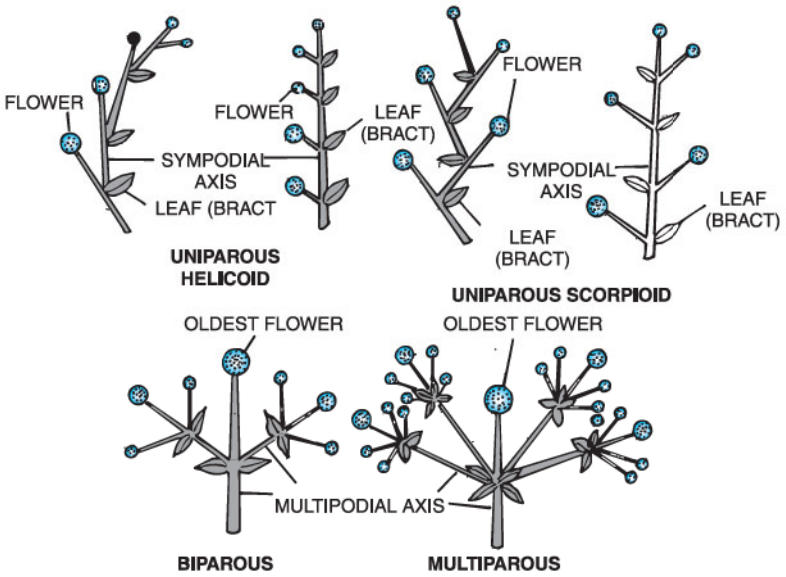


Fig. 48. Kinds of cymose inflorescence.

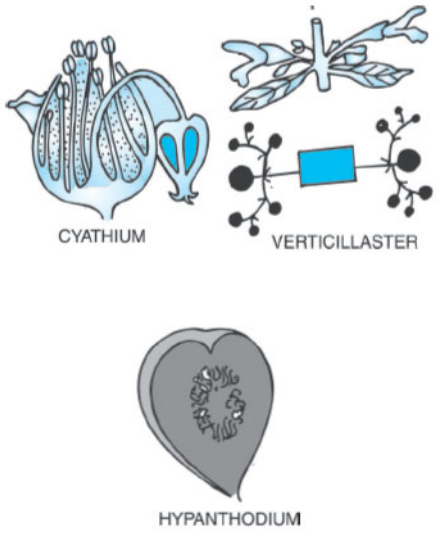


Fig. 49. Special types of inflorescence.

female flowers towards the base *e.g. Ficus* species like Peepal, Banyan etc. (Fig. 50).

(b) Cyathium. This is a special type of inflorescence and is the characteristic of genus *Euphorbia* of family **Euphorbiaceae**. The flowers are naked having no perianth. A male flower is represented by a single **stalked stamen** and a female flower by a single stalked **tricarpellary pistil**. The floral axis is very condensed on which five or more male flowers (stalked stamens) and one female flower (stalked pistil) are aggregated. The group of flowers (inflorescence) is surrounded by a cup like structure called **involucre** which is formed by the fusion of bracts. There are four half-moon shaped glands present at the mouth of this involucre *e.g. Euphorbia* (Fig. 51).

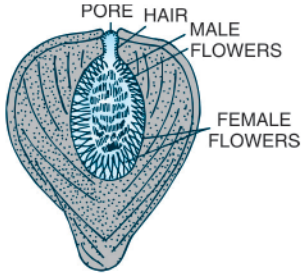


Fig. 50. L.S. Hypanthodium.

(c) Verticillaster. In this case a cluster of sessile or almost sessile flowers appear in the axil of leaf forming a false whorl or verticil at the node. On squarish axis, the inflorescence first is dichasial cyme which is reduced to two scorpioid cymes on two sides. This is a complex inflorescence and found in the family Labiatae *e.g. Ocimum, Salvia, Coleus* etc. (Fig. 52 A-C).

Importance of Inflorescence

1. It provides more chances for cross pollination.

2. Inflorescence makes flowers more conspicuous. Thus insects are attracted for pollination.

3. A large inflorescence also enhances the chance of wind pollination and simultaneously in many flowers.

4. An insect can pollinate many flowers in inflorescence in a single visit.

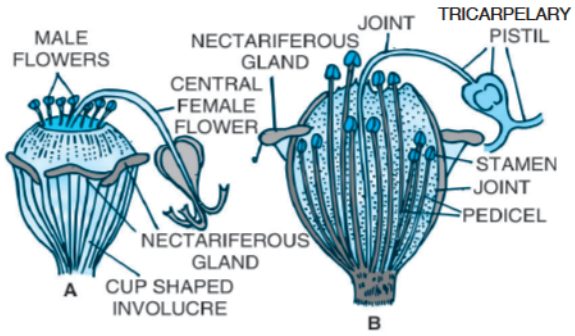


Fig. 51 A. Complete cyathium; **B.** V.S. Cyathium.

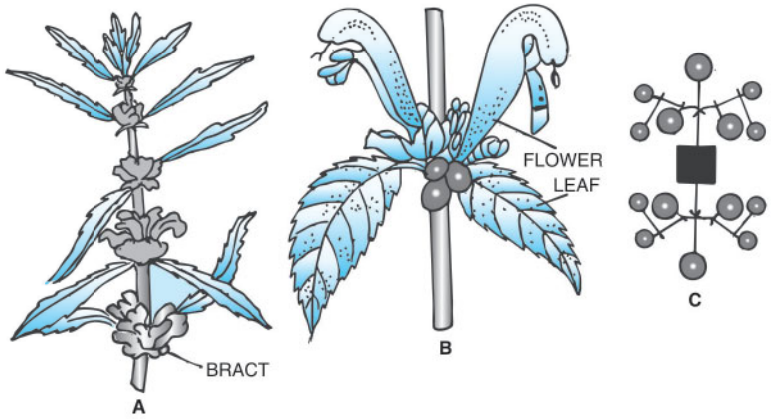


Fig. 52. A–C. Verticillaster inflorescence.

INFLORESCENCE
(An axis bearing flowers)

(A) Racemose (indeterminate), the tip of axis continues to grow, flowers produced laterally.

- **main axis elongated**
  1. **Raceme** — stalked flowers laterally borne; *e.g. Delphinium.*
  2. **Panicle** — branched raceme; *e.g.*; gold mohur.
  3. **Spike** — raceme with sessile flowers; *e.g. Achyranthes.*
  4. **Compound spike/spikelet** — axis branched, made of spikelets consisting of one or more flowers; *e.g., Amaranthus.*
  5. **Catkin** — sessile and unisexual flowers, axis pendulous; *e.g., Morus* (mulberry).
  6. **Spadix** — flowers sessile, axis fleshy, bracts coloured (spathe); *e.g,* banana.
- **main axis shortened**
  1. **Corymb** — floral stalks unequal, flowers lie on the same level; *e.g., Iberis amara* (candytuft).
  2. **Compound corymb** — central axis of corymb branched, each branch bearing corymb; *e.g., Pyrus.*
  3. **Umbel** — floral stalks equal, flowers lie on the same level; *e.g., Hydrocotyle*
  4. **Compound umbel** — axis of umbel branched, each branch bearing umbel; *e.g.* coriander, fennel, carrot.
- **main axis flattened to form receptacle**
  - **Capitulum or head** — florets arising from disc-like receptacle : *e.g.* Sunflower.

(B) Cymose (determinate) tip of axis terminates into a flower, axis growth stops, lateral branches bear flowers; branches also terminate into flower

1. **Uniparous or monochasial** — only one lateral branch produced
   - ***(a) Scorpioid*** — lateral branches develop on alternate sides; *e.g. Tecoma*
   - ***(b) Heliocoid*** — lateral branches develop on the same side; *e.g., Drosera*
2. **Biparous or dichasial** — two lateral branches produced; *e.g. Ixora, Dianthus*
3. **Multiparous or polychasial** — more than two lateral branches produced; *e.g., Calotropis, Nerium*

(C) Special types

1. **Cyathium**
   cup-shaped involucre that encloses one female and many male flowers;
   e.g., Euphorbia.
2. **Verticillaster**
   dichasial cyme reduced to scorpioid cymes, one on each side of the node;
   e.g., Ocimum, Salvia
3. **Hypanthodium**
   cup-shaped receptacle with opening, male flowers near opening of cup, female flowers at base;
   e.g, Ficus (Peepal, Banyan).

Table 19. Differences between Umbel and Capitulum.

Character	Umbel	Capitulum
1. Peduncle	Reduced to a point.	Reduced but flattened to form a receptacle.
2. Flowers	Pedicellate flowers of one type only.	Sessile flowers of one or two types *i.e.* disc florets and ray florets.
3. Examples	Coriander	Sunflower

Table 20. Comparison among Hypanthodium, Cyathium and Verticillaster.

Character	Hypanthodium	Cyathium	Verticillaster
Definition and example	The main axis forms a cup-shaped receptacle with a small opening at the top. Flowers are enclosed within the cup in cymose groups (*Ficus*).	In this inflorescence the involucre forms a cup, single female flower (without perianth) arises in the middle surrounded by a large number of male flowers represented by stalked stamens (*Poinsettia, Euphorbia).*	In this inflorescence, typical of plants with opposite leaves, a cyme arises in each leaf axil. The first axis ends in a flower. The branches arise below it bearing branches in an alternating manner. Flowers are sessile and appear as a cluster (*Ocimum*) around the node.

ADDITIONAL USEFUL INFORMATIONS ABOUT INFLORESCENCE FOR COMPETITIVE EXAMINATIONS

- *Involucel is the whorl of small bracts at the base of secondary umbel/umbellet.*
- *Anthotaxis is the arrangement of flowers on the axis of peduncle e.g. acropetal, basipetal, centripetal.*
- *Strobile is a spike in which the flowers develop in the axils of persistent membranous bracts e.g. Humulus (hop).*
- *Thyrsus is a type of mixed inflorescence when cymose clusters are arranged actropetally e.g. grapevine.*
- *Puya raimondii (32 ft.) is the largest inflorescence of world.*
- *Coenanthium is open hypanthodium.*
- *Petaloid bract is found in Bougainvillea.*
- *Largest Indian inflorescence is Amorphophallus.*
- *Longest inflorescence is Agava.*
- *Edible inflorescence is cauliflower.*
- *Most common inflorescence is spike.*
- *In rhipidium scorpioid cyme, the lateral branches are present on same plane e.g. Solanum nigrum.*
- *In cincinnus scorpioid cyme, the lateral branches are present on angular planes.*

FLOWER

The flower is a highly modified shoot meant essentially for the sexual reproduction of the plant.

PARTS OF A TYPICAL FLOWER

The different parts of a flower are best understood by referring the structure of a typical flower. A flower is generally borne on the lateral side of the peduncle at a node in the axil of a leaf like structure called **bract** (Fig. 53). The bract protects the flower in bud condition. A flower arising in the axil of a bract is called **bracteate** and if the bract is absent at the base of a flower the flower is said to be **ebracteate.** The stalk of the flower is called **pedicel,** which exposes the flower in favourable position for pollination and the flower is called as **pedicellate.** If the pedicel is absent the flower is **sessile.** Some time, there is a very short pedicel present in the flower, such flower is described as **sub-sessile.** In some flowers two small leaf like structure are also present on the flower pedicel called **bracteoles** and the flower is spoken as **bracteolate.** If bracteoles are absent the flower is **ebracteolate.** The pedicel has an upper swollen portion called **thalamus** or **torus.** It is also known as **receptacle.** Thalamus is considered as an axis of the flower. It bears four types of floral leaves arranged in successive whorls

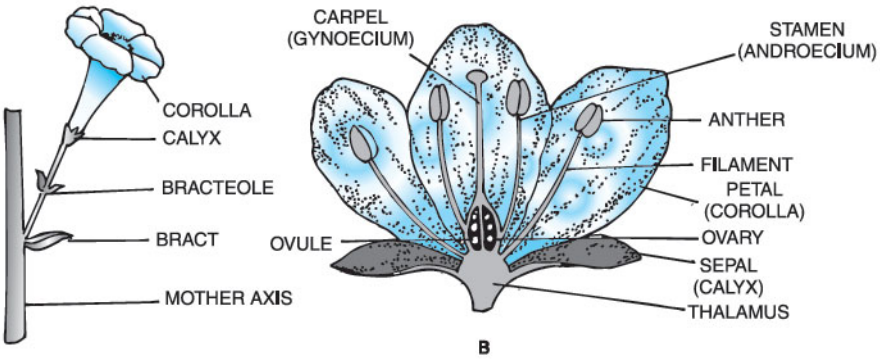


Fig. 53 A. Parts of typical flower; **B.** V.S. of a flower.

the **sepals, petals, stamens** and **carpels.** In group or collectively these whorls are called **calyx, corolla, androecium** and **gynoecium.**

RELATIVE POSITION OF FLORAL PARTS ON THE THALAMUS

The arrangement of floral leaves on the thalamus varies and is of the following types :

A. Hypogyny. When the various whorls of flower are arranged below the ovary, the carpel occupies the central position and other floral parts are borne below it in their respective whorls. Such flowers are called **hypogynous** e.g. China rose (Fig. 54). In such a case ovary is called **superior** and other parts are **inferior.**

B. Perigyny. If the thalamus is flattened out to form a disc or a cup or flask shaped top, the gynoecium will be placed not on the top of the flower but in centre. The remaining three whorls of flower (calyx, corolla and androecium) are usually inserted on the rim of the disc (Fig. 54 C) or cup (Fig. 54 B) or flask (Fig. 54 D) like thalamus. The gynoecium lies at the centre or tip of the thalamus and therefore considered as **superior** and remaining parts inserted on the rim of the thalamus are described **inferior.** Example of perigynous flower with flat (disc) receptacle are strawberry and peas. Perigynous flower with flask shaped receptacle is found in Rose. Cup shaped perigynous condition is present in *Prunus.*

C. Epigyny. In this type the thalamus is also a hollow cup or flask-like structure but the ovary is completely fused with the inner wall of the thalamus or hollow receptacle. The style and stigma of gynoecium are visible above the thalamus. The sepals, petals and stamens are borne on the top of the ovary. The gynoecium is described as **inferior** while other floral parts are **superior** e.g. Sunflower. Coriander and Apple (Fig. 54E).

FLOWER IS A MODIFIED SHOOT

Following evidences can be given in favour of 'flower is a modified shoot' :

(i) Floral buds and shoot buds both are terminal or axillary in position.

(ii) In *Agave* and onion flower buds get modified into vegetative buds or bulbils.

(iii) Anatomy of thalamus, pedicel and stem exhibit similarities. Vascular supply to different appendages resemble with vascular supply of normal leaves.

(iv) In rose flower, sepals resemble with leaves on stem.

(v) In *Degenaria,* stamens are expanded like ordinary leaves and carpels are folded leaves and are not further differentiated into style and stigma.

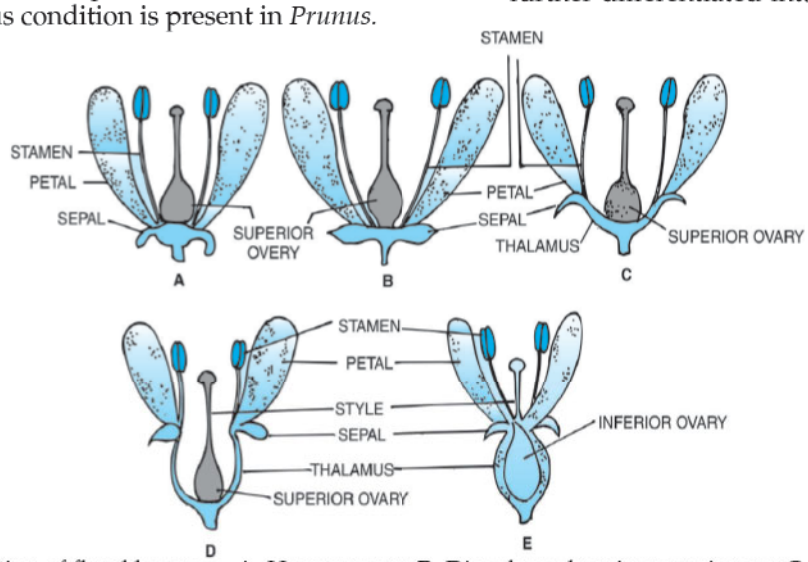


Fig. 54. Insertion of floral leaves — **A.** Hypogynous; **B.** Disc shaped perigynous in pea; **C.** Cup shaped perigynous in *Prunus;* **D.** Flask shaped perigynous in Rose; **E.** Epigynous in *Pyrus* (apple).

(vi) Thalamus is elongated in *Gynandropsis gynandra* and show distinction of long internodes between different floral appendages.

(vii) In *Nymphaea* (water lily), transitional stages can be observed between a sepal and a petal and a petal and a stamen.

CALYX

It is the outrmost whorl of the flower. Sepals of sepals are usually leaf like green in colour and protect the flower in bud condition.

A. Forms of Calyx. The calyx is composed of sepals which may be free or united. If all the sepals in a calyx are free, it is described as **polysepalous** *e.g. Brassica campestris* and if the sepals are united the calyx is spoken as **gamosepalous** *e.g. Petunia*,

The sepals may be coloured like petals called **petaloid** (larkspur).

B. Functions of Calyx

1. The calyx provides **support** to the thalamus and other floral parts.
2. It also **protects the internal floral organs** (petals, stamens and carpels) in bud condition.
3. Calyx also **attracts insects** when becomes coloured or produces nectar.
4. It performs the functions of **photosynthesis.**
5. The calyx of *Hibiscus subdariffa* becomes fleshy due to storage of food and are edible.

EPICALYX

In some plants a whorl of green sepals like structure is present at the base of calyx called **epicalyx.** Epicalyx is considered a whorl of the **bracteoles** and mostly found in the flowers of family *Malvaceae* (*Althaea*, Cotton).

COROLLA

It is second floral whorl present inner to calyx and composed of petals. Corolla protects the more essential whorls of stamens and carpels. The petals are usually brightly coloured due to the presence of pigments fond in chromoplasts of cells. Sometimes the petals may be green in colour called **sepaloid.** If the petals are free from one another in the corolla, the condition is **polypetalous** or **choripetalous** and if there is any degree of fusion between the petals, the corolla is said to be **gamopetalous** or **sympetalous.**

Like of the calyx the corolla is **caducous** (*Grapevine*) mostly **deciduous** and very rarely it is **persistent** (*Heather*).

A. FORMS OF COROLLA

Types of polypetalous corolla are (Fig. 55) :

1. Cruciform. Presence of four, free, unguiculate petals arranged in form of a cross e.g. *Brassica* (Sarson). Each unguiculate petal consists of a lower narrow portion called **claw** and an upper broad portion **limb**.

2. Caryophyllaceous. There are five unguiculate petals. The limbs of petals spread outward and lie at right angle of claw e.g. *Dianthus (Pink)* and Carnation etc.

3. Rosaceous. The petals are five or more than five having very reduced or sessile claw and large broad limb spreading outwardly e.g. Rose.

4. Papilionaceous. It is butterfly-shaped irregular corolla consists of five petals. The posterior petal is largest known **Standard** or **Vexillum.** Two lateral petals are small and free called **Wings** or **Alae,** and are overlaped by the posterior standard petal. The two anterior petals are fused to from innermost boat-shaped structure covering the stamens and carpel of the flower

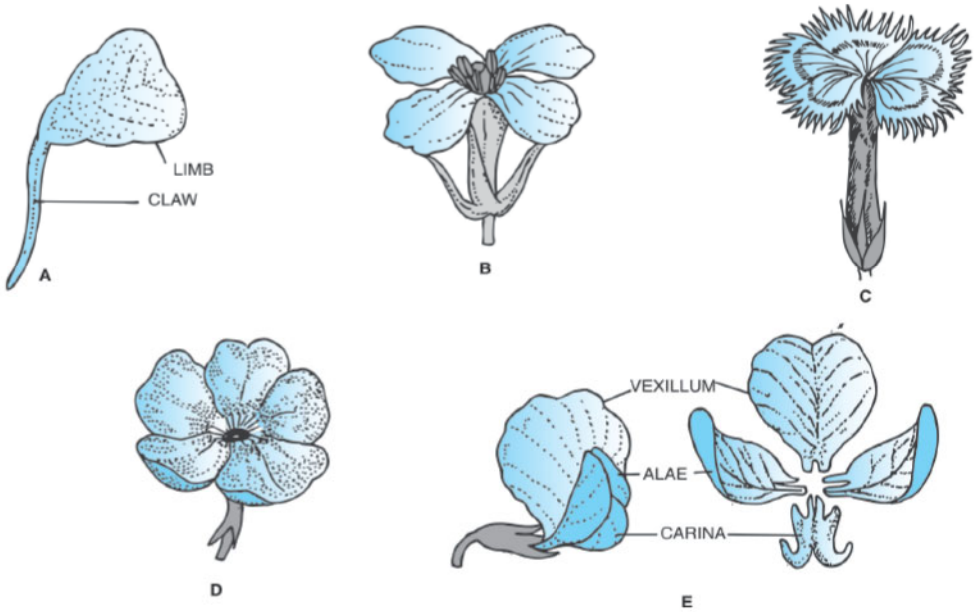


Fig. 55. Polypetalous forms of Corolla – **A.** Single petals of Cruciform corolla; **B.** Cruciform corolla; **C.** Caryophyllaceous; **D.** Rosaceous; **E.** Papilionaceous corolla.

and is spoken as **Keel** or **Carina.** It is overlapped by wings or alae *e.g.* members of family **Papilionaceae** e.g. Pea.

Like of fused calyx, the gamopetalous corolla shows the various degrees of fusion of the petals and accordingly described as **toothed**—almost complete fusion only lobes of petals are free; **fid**— fused upto the half way from the base of corolla tube toward apex and **partite**-fusion less than half from base to apex of corolla.

Various forms of gamopetalous (Fig. 57)

Regular Corolla

1. Tubular. Tube like structure *e.g.* disc floret of sunflower.

2. Campanulate. Bell shaped *e.g. Cucurbita* and *Physalis.*

3. Infundibuliform. Funnel shaped e.g. *Petunia.*

4. Salver-shaped. Corolla tube is long and narrow with the spreading lobes at right angle e.g. *Vinca rosea* and *Clerodendron.*

5. Rotate. Corolla tube is quite short and the limbs are present at right angle like **spokes of a wheel** e.g. *Solanum nigrum* and *Nyctanthes.*

6. Urceolate. Urn-shaped e.g. *Bryophyllum.*

Irregular Corolla

7. Ligulate. It is strap shaped corolla. Five petals fused to form a small narrow tube at the base which splits on one side and become flattened like a strap e.g. ray florets of sunflower.

8. Bilabiate. Corolla is bilipped. If both the lips from wide open mouth then corolla is described as bilabiate ringent *e.g. Salvia* (Fig. 57). If two lips are placed close together and the mouth is closed-termed as **bilabiate personate** e.g. *Antirrhinum* (Fig. 56).

9. Spurred. One or two petals in a corolla forming a beak like structure e.g. Larkspur.

B. Functions of Corolla

1. Corolla attracts insects for **pollination** when they are beautiful and coloured or forms nectar pockets on the petals or collect nectar at its base.
2. Sometime scented ducts are present on the petals which also help in attracting insects. These ducts produce scent which is used in the preparation of various perfumes.
3. Corolla also **protects the essential organs** (stamens and carpels) of a flower in young condition.
4. The corolla also regulates the entry of a particular type of insect by forming various shapes.

PERIANTH

When the two outer accessory whorls are not differentiated into sepals and petals and all the floral leaves are alike in these whorls or sometime there is a presence of only one whorl it is termed as perianth. In the perianth each floral part is known as tepals. When the tepals are free it is said to by **polyphyllous** and if the tepals are fused are fused the perianth is described as **gamophyllous.** The tepals may be brightly coloured or **petaloid** as in *Gloriosa superba* or they may be green or **sepaloid** e.g. *Chenopodium.* The perianth is represented by two white shining structures termed as *Lodicules* e.g. Wheat and Grasses etc.

ANDROECIUM

Androecium is the third essential whorl which consists of stamens or male reproductive part of a flower. Each stamen is composed of a slender stalk like **filament** supporting a knob like structure called **anther.** Each anther usually consists of two anther lobes connected with the help of a **connective** which can be clearly seen on the dorsal side as an extension of the filament (Fig. 57). Some time the connective becomes enlarged and two anther lobes are separated apart called **divaricated** or **divergent** anther lobes (Fig. 57 B). In *Salvia* the connective is quite enalarged and fixed to the filament at right angle, separating two anther lobes termed as **distractile** thus forming a lever mechanism (Fig. 57). When there are

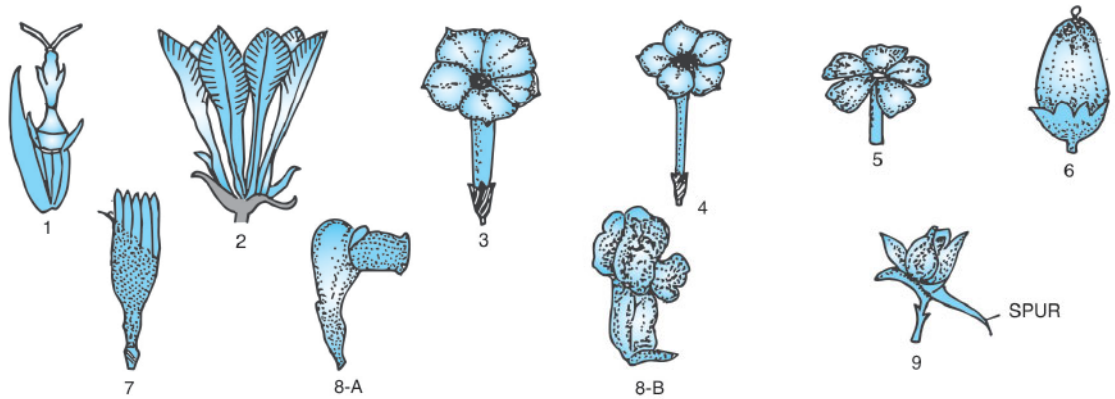


Fig. 56. Gamopetalous forms of corolla — **1.** Tubular; **2.** Campanulate; **3.** Infundibuliform; **4.** Salver shaped; **5.** Rotate; **6.** Urceolate; **7.** Ligulate; **8.** Bilabiate : **A.** Ringent, **B.** Personate, **9.** Spurred.

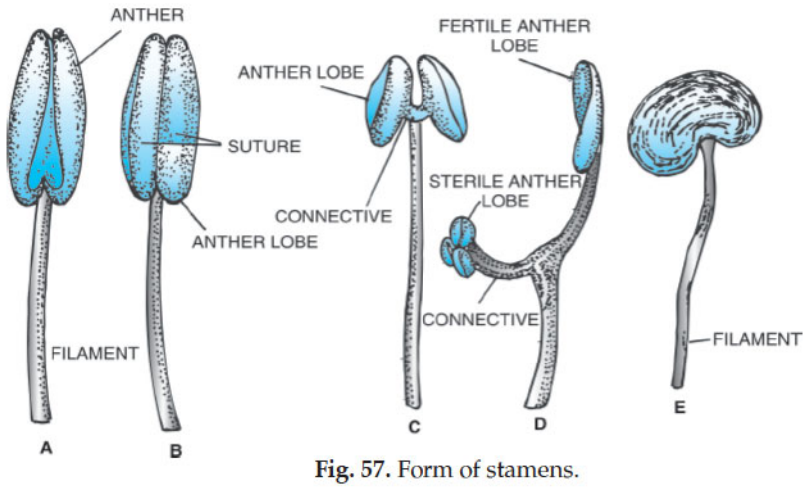


Fig. 57. Form of stamens.

two lobes in the anther, it is described as **bithecous,** but in certain cases there is only one kidney shaped anther lobe known as **monothecous** (Fig. 57E) e.g. members of family **Malvaceae** (*Althaea* etc). Each anther lobe has two **pollen sacs** or **pollen chambers** containing large number of minute rounded bodies called as pollen grains. Sometime the stamens becomes sterile and do not form pollen grains called as **staminodes.**

A. FORMS OF ANDROECIUM

Stamens are **free** from each other (Fig. 58).

1. Polyandrous. All the stamens are free in the androecium e.g. *Brassica.*

2. Epipetalous. Filaments of the stamens adnate with petals. It is found mostly in gamopetalous corolla e.g. *Petunia,* Brinjal (Fig. 58).

3. Epiphyllous. Stamens attached with sepals e.g. *Asphodelus.*

4. Episepalous. Stamens attached with sepals e.g. *Verbena.*

5. Gynandrous. When the anthers of stamens united with stigma of carpels forming the **gynostegium** e.g. *Calotropis* (AK) (Fig. 58).

6. Inserted. Stamens are shorter than the corolla tube and remain hidden inside it e.g. *Petunia.*

7. Exerted. When stamens come out from corolla tube e.g. *Acacia* (Fig. 58).

8. Didynamous. There are four stamens out of which two stamens are larger and two are shorter in length e.g. *Ocimum* (Fig. 58).

9. Tetradynamous. There are six stamens in which four stamens are large and two are short e.g. *Brassica campestris* (Fig. 58).

10. Alternipetalous. There is a single whorl of stamens. The number of stamens is equal to the number of petals and they alternate with the petal lobes e.g. *Solanum nigrum.* In case of sepals the condition is **alternisepalous.**

11. Antipetalous. Same as above, but the stamens are present opposite to the petal lobes e.g. *Coriander.* In case of sepals the condition is **antiphyllous.**

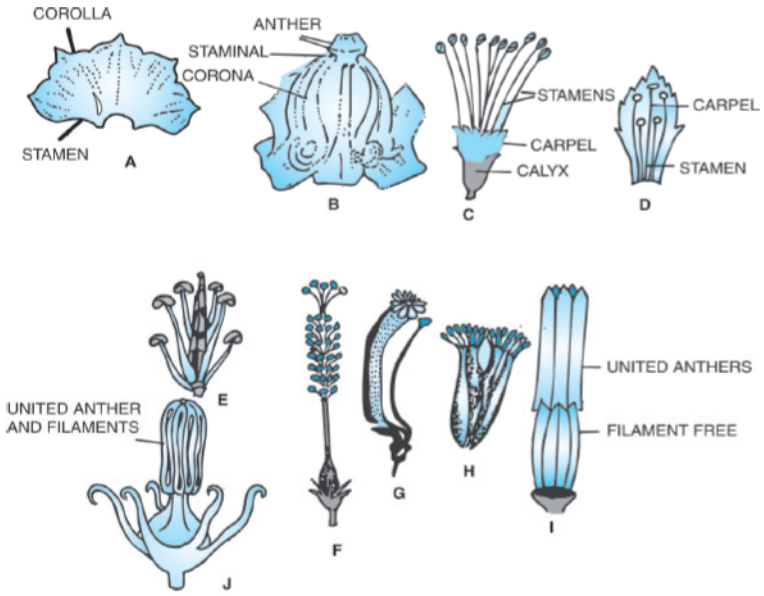


Fig. 58. Forms of androecium – **A.** Epipetalous; **B.** Gynostegium; **C.** Exerted stamens; **D.** Didynamous; **E.** Tetradynamous; **F.** Monoadelphous; **G.** Diadelphous; **H.** Polyadelphous; **I.** Syngenesious; and **J.** Synandrous.

12. Diplostemonous. The stamens are double the number of petals and present in two whorls. The outer whorl of stamens is alternating with petals (**alternipetalous**), while inner whorl is opposite to petals (**antipetalous**) e.g. *Cassia* and *Murraya exotica.*

13. Obdiplostemonous. It is reverse of diplostemonous. The outer whorl of stamens is opposite to petals (**antipetalous**) while inner whorl of stamens is alternating with petals (**alternipetalous**) e.g. Pink.

14. Isostemonous. All the stamens in a flower are alike in shape, size and mode of dehiscence etc.

15. Heterostemonous. The stamens in a flower differ in their shape, size and mode of dehiscence e.g. *Cassia.*

Forms of fused androecium (Fig. 58)

1. Adelphous. The stamens are fused by their filaments but the anthers are free. If the filaments of all the stamens fused to form one groups, is termed as **monoadelphous** e.g. *Hibisus rosa sinensis* (Fig. 58) When they are fused in two groups called **diadelphous** e.g. *Pea* (Fig. 58) or some time fused in more than two groups and described as **polyadelphous** e.g. *Citrus* (Fig. 58).

2. Syngenesious or **Synantherous.** In this case the filaments of stamens are free and anthers are fused by their sides to form a ring around the style e.g. Sunflower (Fig. 58).

3. Synandrous. When both filaments and anthers of the stamens are fused completely e.g. *Cucurbita, Phyllanthus* (Fig. 58).

B. FIXATION OF ANTHERS

It is the attachment of the filament to the anthers (Fig. 59)

The anther is said to be **adnate** when the filament runs up the whole length in between the anther lobes e.g. *Buttercup, Magnolia;* **basifixed** - when filament is attached to the base of anther e.g. *Brassica* (Sarson), *Raphanus* etc; dorsifixed – when filament is attached to the back of anther e.g. *Passiflora* and the fixation is **versatile** when filament is attached to the back of the anther and the anther can swing freely in the air e.g. grasses.

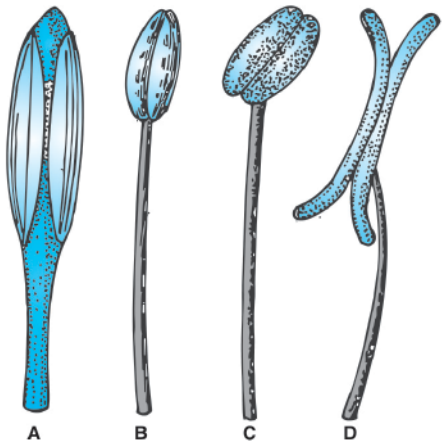


Fig. 59. Fixation of Anthers **A.** Adnates; **B.** Basifixed; **C.** Dorsifixed; **D.** Versatile.

GYNOECIUM

The gynoecium or pistil is the fourth essential whorl of female reproductive part of the flower and may be composed of one or more carpels. A carpel has three distinct parts, namely the **ovary, style** and **stigma** and is a highly modified leaf folded along the midrib. The margins of the leaf fused to form the ventral suture of the carpel and the midrib side represents the dorsal suture. A cushion like parenchymatous outgrowth develops on the ventral suture called **placenta** on which the ovules are borne.

The ovary is a basal swollen portion of the pistil containing one of more chambers or loculi and accordingly the ovary is known a unilocular, bilocular, trilocular, tetralocular, pentalocular and multilocular. The wall of the ovary after fertilization is known as **pericarp.** After fertilization, at maturity, the ovary develops into a **fruit** while ovules form **seeds**.

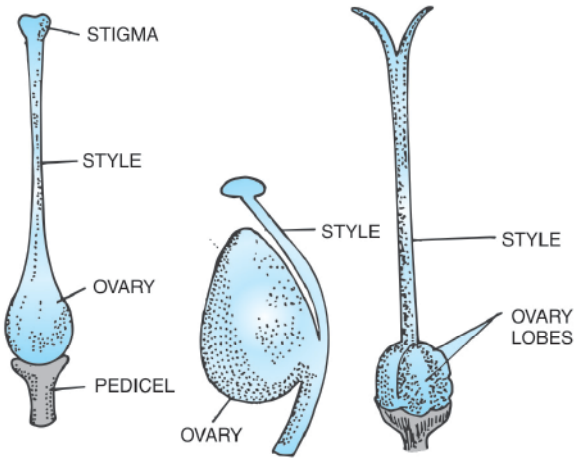


Fig. 60. Types of styles.

The style is the slender projection of the ovary which is meant for raising the stigma on which pollen grains are deposited during pollination. Style may be hollow or solid and is of three types based on its origin from ovary (Fig. 60). The terminal style is formed by protruding the ovary into a long or shot style. It is of common occurrence. Lateral style arises from one side of ovary e.g. Mango, while **gynobasic** style originates from the base of the ovary or centre of thalamus e.g. *Salvia* and *Ocimum.* Style is absent in Buttercup and Lotus etc. Style is branched also in some flowers.

The stigma is the teminal end of the style and receives the pollen grains. It may be knob like or slightly pointed, even some what elongated. The stigma may be lobed, funnel-shaped, branched or feathery. The surface of stigma may be hairy, sticky, smooth or rough.

A sterile pistil devoid of mature ovule is called as **pistillode.**

FORMS OF GYNOECIUM

On the basis of number of carpels is the gynoecium is of following types :

When gynoecium is represented by a single carpel it is termed as monocarpellary e.g. Pea. The ovary is described as simple ovary. If the number of carpels in

the gynoecium is 2, 3, 4 and 5, it is said to be bicarpellary, tricarpellary, tetracarpellary and pentacarpellary respectively. When the gynoecium contains more than five carpels, it is called polycarpellary.

On the basis of free and fused carpels the gynoecium is of following nature :

Apocarpous. There are two or more carpels in a gynoecium which are free from each other e.g. *Ranunculus* (Buttercup), *Aconitum*.

Syncarpous. In this form two or more carpels are fused together to form a single compound ovary e.g. *Petunia*, *Althaea* etc.

The fusion of carpels may take place in different ways. They may be fused in the region of ovaries only, but the style and stigma are free e.g. Pink. Fusion may be in ovaries and styles region only and stigmas are free e.g. China-rose or in some cases all the three parts e.g. ovaries , styles and stigmas are fused e.g. *Petunia*, *Solanum melongena*.

In case of oleander the fusion occurs in between style and stigma only, the ovaries are free, while in *Calotropis* (Ak) the fusion occurs only by stigmas, the ovaries and styles are free. In case of *Calotropis* where ovaries and styles are free the gynoecium is considered as **apocarpous.**

PLACENTATION

Placentation is the mode of arrangement of placentae or ovule bearing cushion of parenchymatous cells within the ovary. The placentation is of following types (Fig. 61) :

1. Marginal. This is a simple type of placentation found in **monocarpellary** (simple) pistil or polycarpellary apocarpous pistils. The **longitudinal placenta** develops

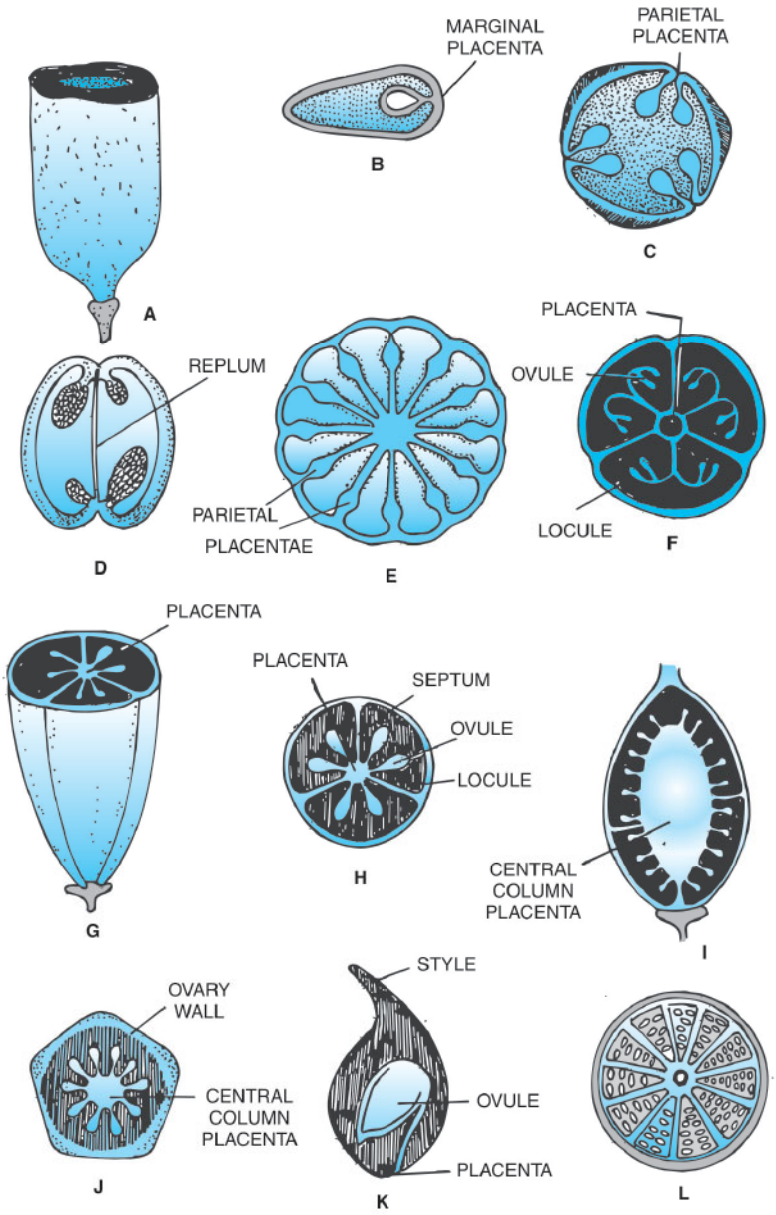


Fig. 61. Types of placentation : **A-B.** Marginal placentation; **C-F.** Types of parietal placentation; **G-H.** Axile placentation; **I-J.** Free central; **K.** Basal and **L.** Superficial.

Table 21. Differences between Marginal and Parietal placentation.

Characters	Marginal Placentation	Parietal Placentation
1. Location	In monocarpellary or simple ovary	In compound or syncarpous ovary.
2. Placenta	Single longitudinal placenta beary ovules attached to ovary wall.	Two or more longitudinal placentae beary ovules attached to ovary wall.
3. Locules	Ovary is always unilocular	Ovary can be unilocular or can become falsely bilocular due to ingrowth of false septum or replum.

on the **ventral suture** of the ovary bearing one or two rows of ovules. The ovary is **unilocular.** *e.g.* Pea, Larkspur and *Cassia* (Fig. 61 B).

2. Parietal. It occurs in syncarpous (compound) pistils in which the ovary is **unilocular.** The placentae develop along the fused margins of the adjacent carpels on the parietal wall of the ovary. The number of placentae is equal to the number of fused carpels *e.g. Fumaria* and *Viola* (Fig. 61 C). The parietal placentation is modified in different ways in the following cases :

In *Brassica campestris* two placentae develop on the parietal wall of the bicarpellary syncarpous, unilocular pistil, but soon a **false septum or replum** develops in between the two placentae making the ovary **bilocular** (Fig. 61 D).

In Poppy the placentae protruding inwards into the cavity of ovary form incomplete septa. The ovules develop on these septa but the ovary remain **unilocular** (Fig. 61 E).

In *Cucurbita* the placentae grow in the cavity of ovary towards the centre and then turn outwardly bearing the ovules on their free turned ends. Ovary is unilocular but it gives a false appearance of axile palcentation (Fig. 61F).

In *Cucurbita* the placentae grow in the cavity of overy towards the centre and then turn outwardly bearing the ovules develop from the central cloumn or axis which is formed by the fusion of margins of carpels. In certain cases the number of chambers (loculi) increases due to the false septum formation *e.g. Datura, Tomato* etc. (Fig. 61 G, H).

4. Free central. It is reported in a compound pistil in which ovary is unilocular. The placenta bearing the ovules is present in the centre of ovary forming a central column. It has no connection with ovary wall. The central placenta either arise from the **torus** or **thalamus** *(Primrose)* or the partition walls (septa), in the young ovary having axile placentation soon breakdown leaving the central column bearing ovules *e.g. Dianthus* (Fig. 61, J).

5. Basal. In basal placentation the ovary is unilocular and placenta develops directly from torus bearing a single ovule at the base of ovary. The ovary may be simple Buttercup (Fig. 61 K) or compound (Sunflower). Sometimes an ovule is attached at the apex of the unilocular ovary and hangs downwardly. Its is described as **Apical placentation** *e.g. Cannabis* **(Bhang)**. *Ceratophyllum.*

6. Superficial. In this the ovary is **multilocular** and the placentae develop all around the inner surface of the partition walls bearing ovules *e.g. Nymphaea* (Water lily, Fig. 61 L).

AESTIVATION

It is the arrangement of petals in a flower bud in respect to one another. The aestivation may be of following types (Fig. 62).

1. Open. The margins of adjacent petal lobes are quite apart to one another.

2. Valvate. Petals in a whorl are quite close to each other without overlapping e.g. *Mimosa, Acacia.*

3. Twisted or Contorted. When one margin of a petal overlaps the adjacent petal lobe and the other margin is overlapped by the adjacent petal e.g. *Nerium* and China rose.

4. Imbricate. It is an irregular types of overlapping of petals in the floral whorl and is of two types :

(i) Ascending imbricate. The posterior petal is overlapped by two lateral petals which in their turn are overlapped by two anterior petals e.g. *Cassia* and *Caesalpinia.*

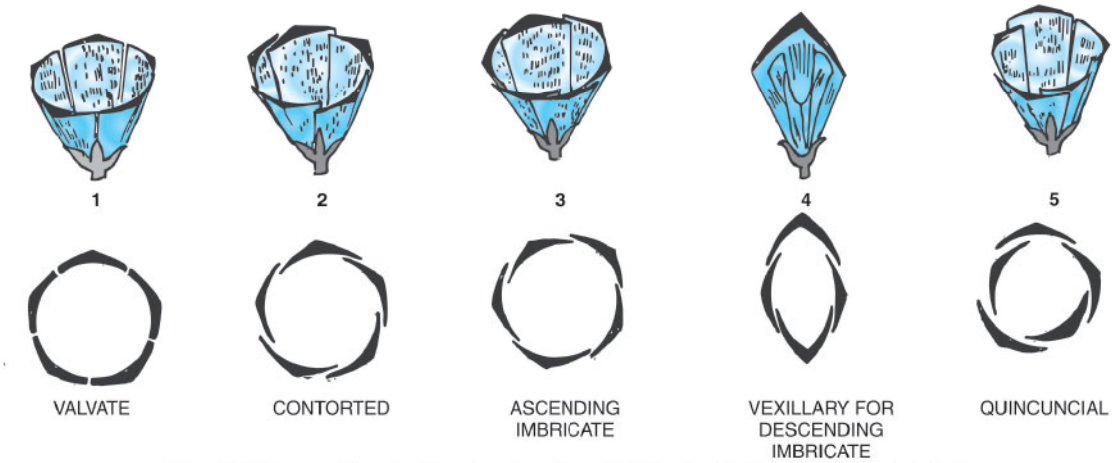


Fig. 62. Types of Aestivation in Corolla—**1.** Valvate; **2.** Contorted or twisted; **3.** Ascending imbricate; **4.** Descending imbricate; **5.** Quincuncial.

(ii) Descending imbricate. The posterior petals is overlapping the two lateral petals which in their turn overlap the two anterior petals. It is also known as **Vexillary** aestivation e.g. Pea, *Lathyrus.*

5. Quincuncial. There are five petals, out of which two are completely external, two are internal and fifth petal having one margin external while other margin is internal e.g. *Psidium guyava* (Guava) and *Punica granatum* (Anar).

FRUIT

Botanically, a **fruit is a matured ovary with or without seeds.** In some fruits, other structures derived from other floral parts or from receptacle may become the part of fruit. Furthermore, a fruit may consist of several matured ovaries remaining together as a unit. So, a fruit may be defined as a structure made up of one or more matured ovaries together with any accessory structures closely associated with them. After fertilization, ovary forms fruit and ovules change into seeds. Such fruits are called **eucarp**. Some fruits are formed without fertilization and do not bear seeds. These fruits are known as **parthenocarpic** *e.g.* Banana and Grapes. When other floral parts like thalamus, perianth, bracts etc. have fused with pericarp to form a part of the fruits, they are called **pseudocarp**.

The mature wall of the ovary in the fruit is called **pericarp**. The structure of pericarp varies greatly in different kinds of fruits. In some, three distinct layers may be differentiated *i.e.* an outer layer called **epicarp** or **exocarp**, a middle layer called **mesocarp** and inner layer called **endocarp**. **Pomology** is the branch of horticulture that deals with the study of fruits and their cultivation.

The main **functions** of the fruit are :

1. To protect the seeds in young and immature condition.

2. Dispersal of the seeds to distant places, even during the unfavourable conditions.

3. Some single seeded fruits are sown as a whole fruit. In such cases the fruit also provides nourishment to developing seedling e.g, Wheat and Maize etc.

4. Fruits are a source of sugars, pectins, organic acids, vitamins and minerals.

5. Many of the fruits are eaten by people.

KINDS OF FRUITS

Fruits are of many kinds. In general, fruits may be classified as:

(a) Simple fruits. They develop from a single flower having **monocarpellary** and **syncarpous** pistil.

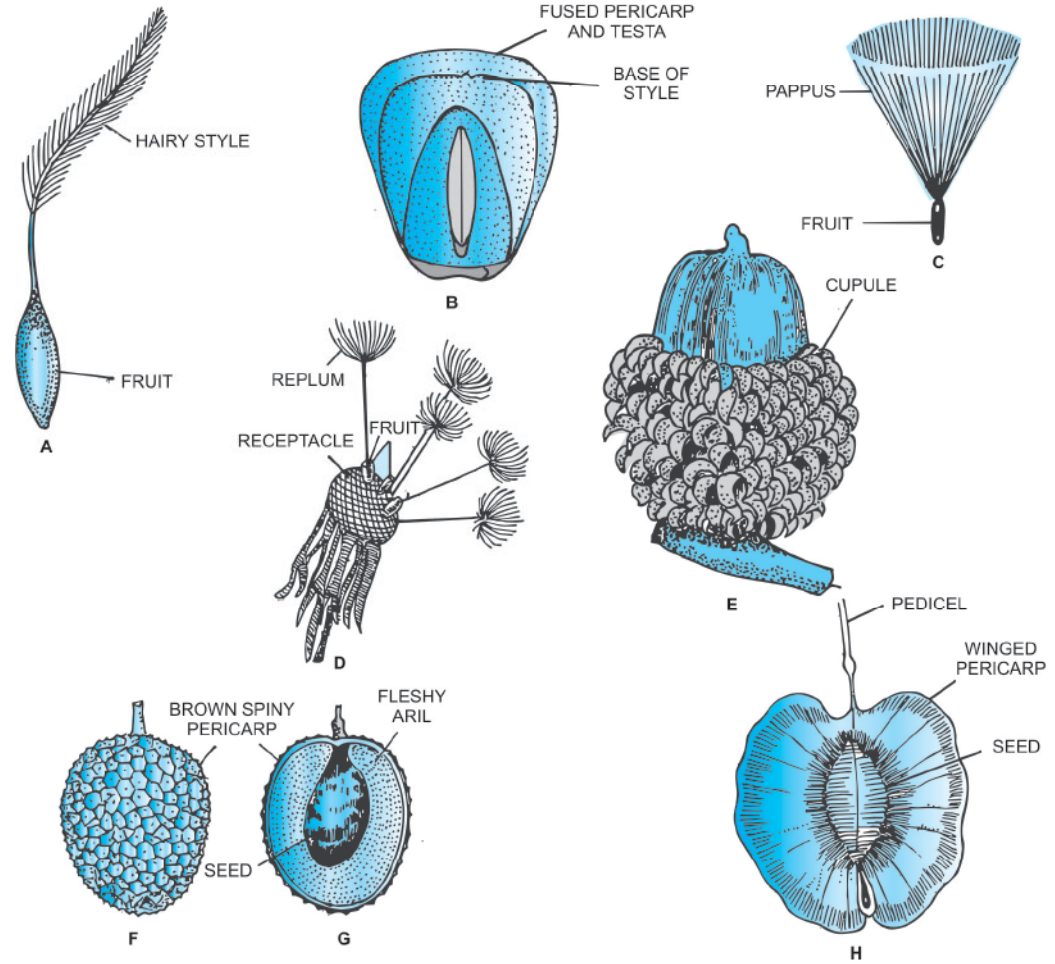


Fig. 63 A. Achene of *Clematis;* **B.** Caryopsis of *Maize;* **C.** Cypsela of *Sonchus;* **D.** Cypsela of *Dendelion;* **E.** Nut of Oak; **F—G.** Nut of Litchi and **H.** Single samara of Elm.

(b) Aggregate fruits. They are also produced from a single flower having **polycarpellary** and **apocarpous** pistil. A single part of fruit is called as **fruitlet**, *e.g*, *Michelia*, strawberry, custard apple

(c) Composite Fruits. When the entire **inflorescence** with its flowers and peduncle etc. are changed into a single fruit *e.g.* pineapple.

(a) Simple Fruits

These are of two types :

I. Simple dry fruits

II. Simple succulent (fleshy) fruits.

I. Simple dry fruits. The fruit wall or pericarp is dry. These are further divided into three types :

(i) Achenial Fruits. These are single seeded indehiscent fruits (Fig. 63).

(a) Typical Achene. Small, one-seeded; seed attached to pericarp at one point only; pericarp readily separable from seed coat (*Clematis*, *Ranunculus*).

(b) Grain or **Caryopsis.** Small, one-seeded; seed coat fused to pericarp over its entire surface (corn, wheat, oats, rye and barley).

(c) Samara. A winged achene *e.g.* elm.

(d) Nut. Pericarp hard or crustaceous throughout; usually from a compound pistil only one carpel of which develops; mostly one-seeded, usually with an involucre (chestnut, *Anacardium*, *Trapa*, acorn and beechnut) (Fig. 65).

The nut of Litchi develops from **tricarpellary, syncarpous, superior** ovary having brown leathery and brittled pericarp. The fleshy white edible portion is the **aril** (outgrowth of funicle) of seed.

(e) Cypsela. It develops from an inferior, **unilocular, uniovuled, bicarpellary syncarpous** pistil with **basal placentation** *e.g.* Sunflower. Sometimes the hairy sepals called as **pappus** are attached with fruit which help in the dispersal of fruit *e.g. Sonchus* and *Dendelion*.

(ii) Capsular Fruits. Those which split open at maturity and are many seeded :

(a) Legume. Developed from a simple pistil; splitting along two sutures into two valves (peas, beans and black locust) (Fig. 64 A).

(b) Follicle. Developed from a simple pistil; splitting along one suture (milkweed, columbine and larkspur) (Fig. 64 C).

(c) Capsule. Developed from a compound pistil (poppy, purslane, iris, St. John'swort and morning glory).

(1) Siliqua. The elongated two-loculed capsule of the mustard family *e.g.* mustard (Fig. 64 D).

(2) Silicula. A short, broad siliqua (Shepherd's-purse, peppergrass) (Fig. 64 E).

(3) Pyxis. A capsule with circumscissile dehiscence (*Portulaca*).

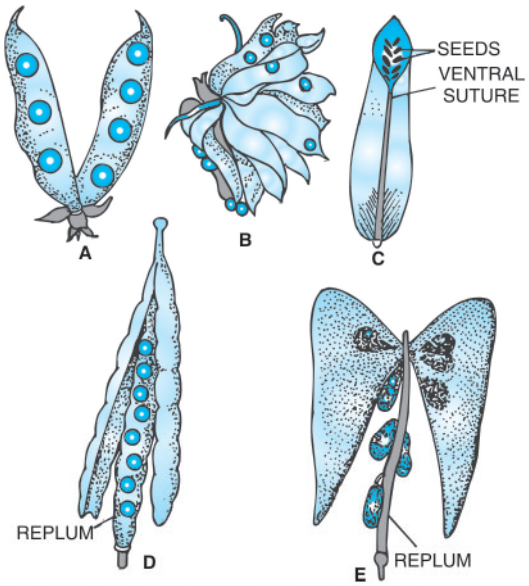


Fig. 64. Capsular fruits (Dehiscent fruits) **A .** Legume of Pea; **B.** Legumes of *Abrus precatorius*, **C.** Follicle of Larkspur; **D.** Siliqua of Mustard and **E.** Silicula of *Capsella*.

II. Fleshy Fruits. The fruits in which all or most of the pericarp is soft and fleshy at maturity.

1. Berry, in which the entire pericarp becomes fleshy. **Examples:** Grapes, banana, tomato. A berry with a hard rind is called a **Pepo** (**Examples:** Watermelon,

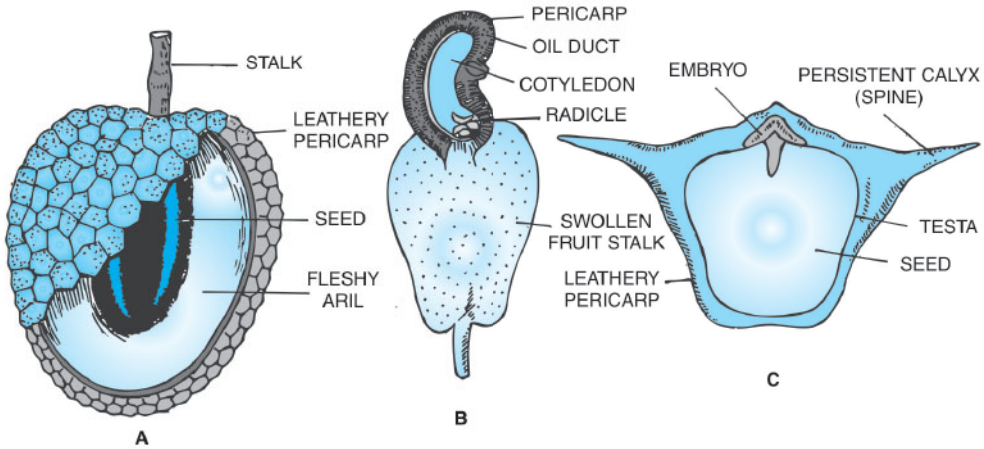


Fig. 65 Nuts—**A.** Litchi; **B.** *Anacardium* (Cashewnut); **C.** *Trapa*.

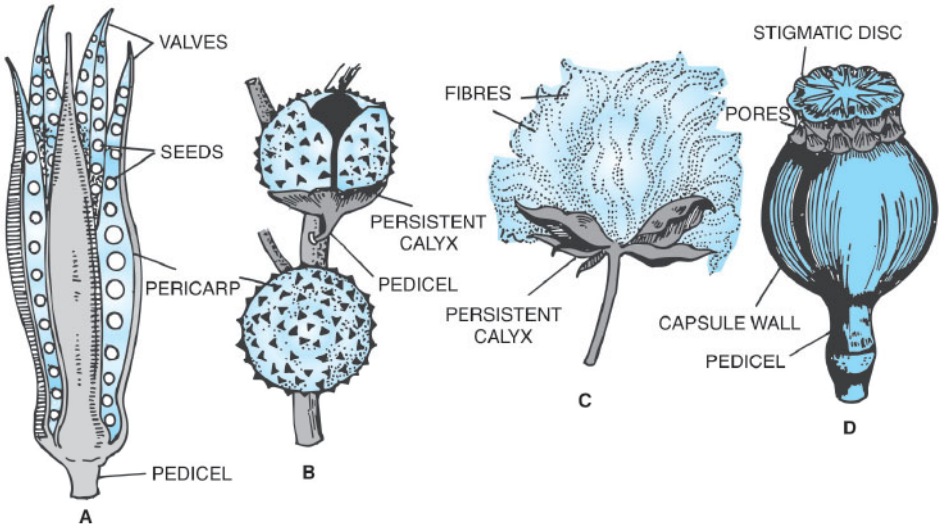


Fig. 66. Capsular fruits—**A.** Bhindi; **B.** *Datura*; **C.** Cotton; **D.** Poppy.

cucumber, cantaloupe). A berry with a leathery rind is called a **hesperidium** (**Examples :** Oranges, grape fruit, lemon). **Blausta** *e.g.* pomegranate and **amphisarca** *e.g. Aegle marmelos* are the special type of modified berry fruits (Fig. 67).

2. Drude, in which the exocarp is a thin skin, the mesocarp is thick and fleshy, and the endocarp hard and stony. The endocarp ("stone" or "pit") encloses one, rarely 2 or 3 seeds. **Examples :** Peach, plum, olive, cherry, apricot (Fig. 67).

The coconut a fibrous drupe develops from compound and superior pistil. It has stony endocarp, fibrous mesocarp and membranous epicarp. The air is enclosed in the fibrous mesocarp which makes the fruit light for floating on water surface. The white **endosperm** of the seed is the edible portion which contains **milk of Coconut.**

3. Pome. Pome is an inferior (ovary), two or more seeded, fleshy, syncarpous fruit surrounded by thalamus. The fleshy edible part is composed of thalamus. The true fruit lies within *e.g.* apple, pear, loquat etc. (Fig. 67).

(iii) Schizocarpic or splitting fruits. The fruits into single seeded parts at maturity. These single seeded parts may be **indehiscent** known as **mericarps** or **dehiscent** called **cocci.** They are of the following types:

(a) Cremocarp. The fruit breaks from below upward into two single seeded, indehiscent segments called **mericarps.** The mericarps are attached to the tip of a central axis or **carpophore** *e.g.* Coriander, Fennel etc. (Fig. 68 A)

(b) Carcerulus. The fruit splits into many single seeded and indehiscent mericarps *e.g. Ocimum* and *Althaea rosea.*

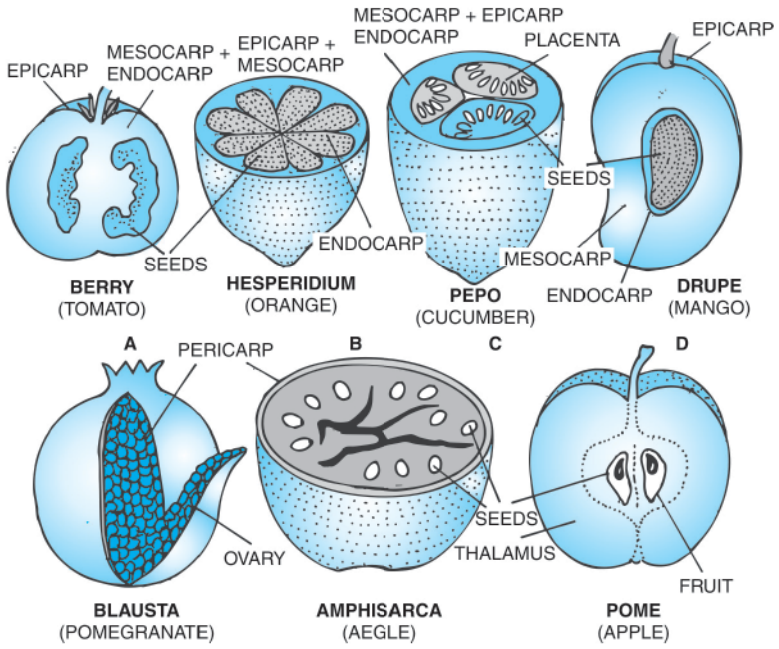


Fig. 67. Some fleshy fruits.

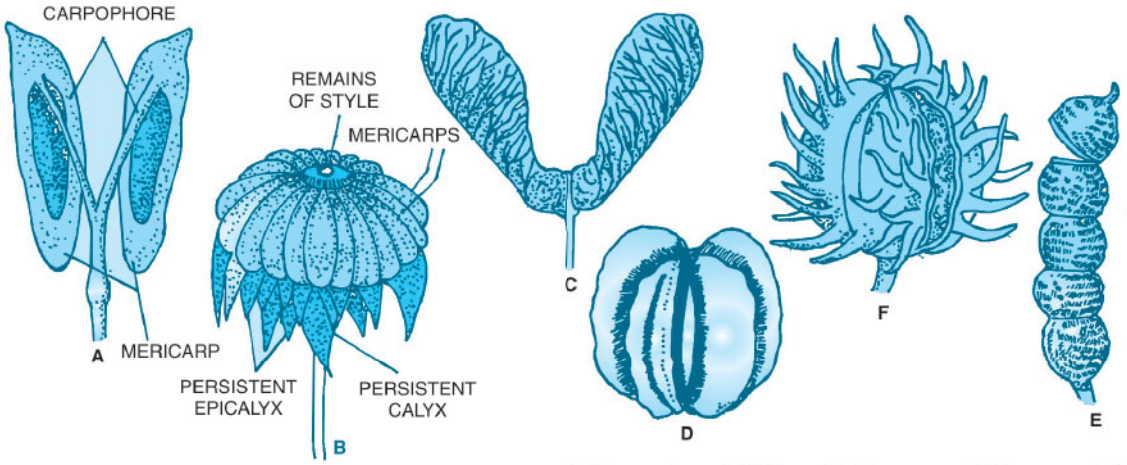


Fig. 68. Schizocarpic fruits. **A.** Cremocarp of Fennel : **B.** Carcerulus of *Althaea;* **C.** Compound Samara of *Acer;* **D.** Compound samara of *Dodonaea* : **E.** Lomentum of *Acacia* and **F.** Regma of Castor.

(c) Compound samara. The samara splits at maturity into two or three single seeded, indehiscent and winged mericarps in Acer and *Dodonaea.*

(d) Lomentum. The mature fruit is constricted. It splits off transversely into single seeded indehiscent mericarps in *Acacia* as **lomentaceous pod** or in Radish as **lomentaceous siliqua.**

(e) Regma. The mature fruit breaks into one seeded dehiscent parts called **cocci** *e.g.* Castor fruit

(b) Aggregate fruits

An aggregate fruit is a cluster of several to many ripened ovaries produced by a single flower and borne on the same receptacle. The individual ripened ovaries may be drupes (rasberries and black berries), achenes (butter cup) etc. (Fig. 69).

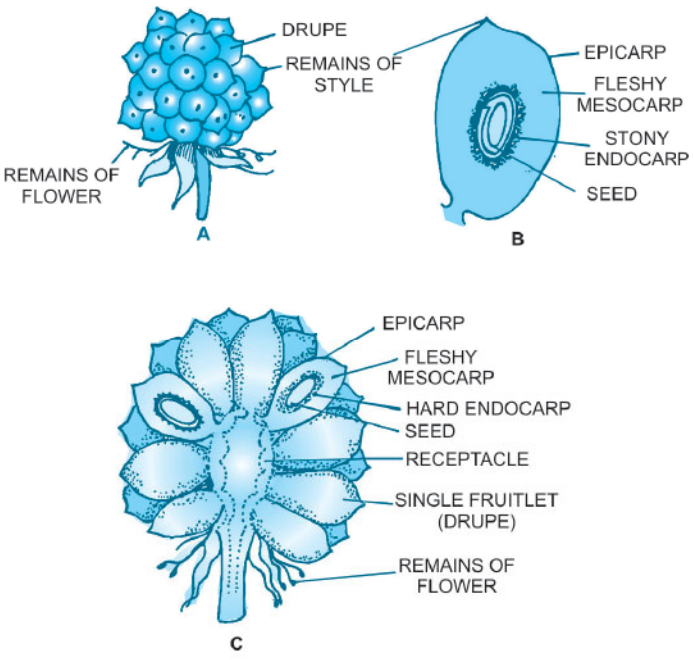


Fig. 69. (A–C). Etaerio of drupes in rasberry. **A,** external view ; **B,** L.S. of drupes; **C.** L. S. of etaerio of drupes.

(c) Multiple (Composite) fruits

A multiple fruit is a cluster of several to many ripened ovaries produced by several flowers crowded on same inflorescence. **Sorosis** is a type of composite fruit developing from a spike or spadix. In such cases flowers fuse by their succulent perianth. The inflorescence axis becomes fleshy by hypertrophy forming a compact mass, *e.g.* Pineapple, Jack fruit and Mulberry. **Syconus** (Fig. 70) is also a type of multiple (composite) fruit and in this case the fruit is produced from the entire hypanthodium inflorescence *e.g.* (*Ficus*).

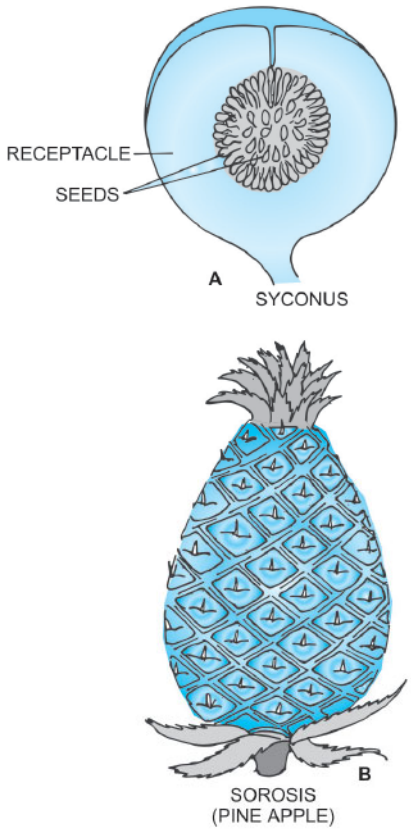


Fig. 70. Multiple or composite fruits.

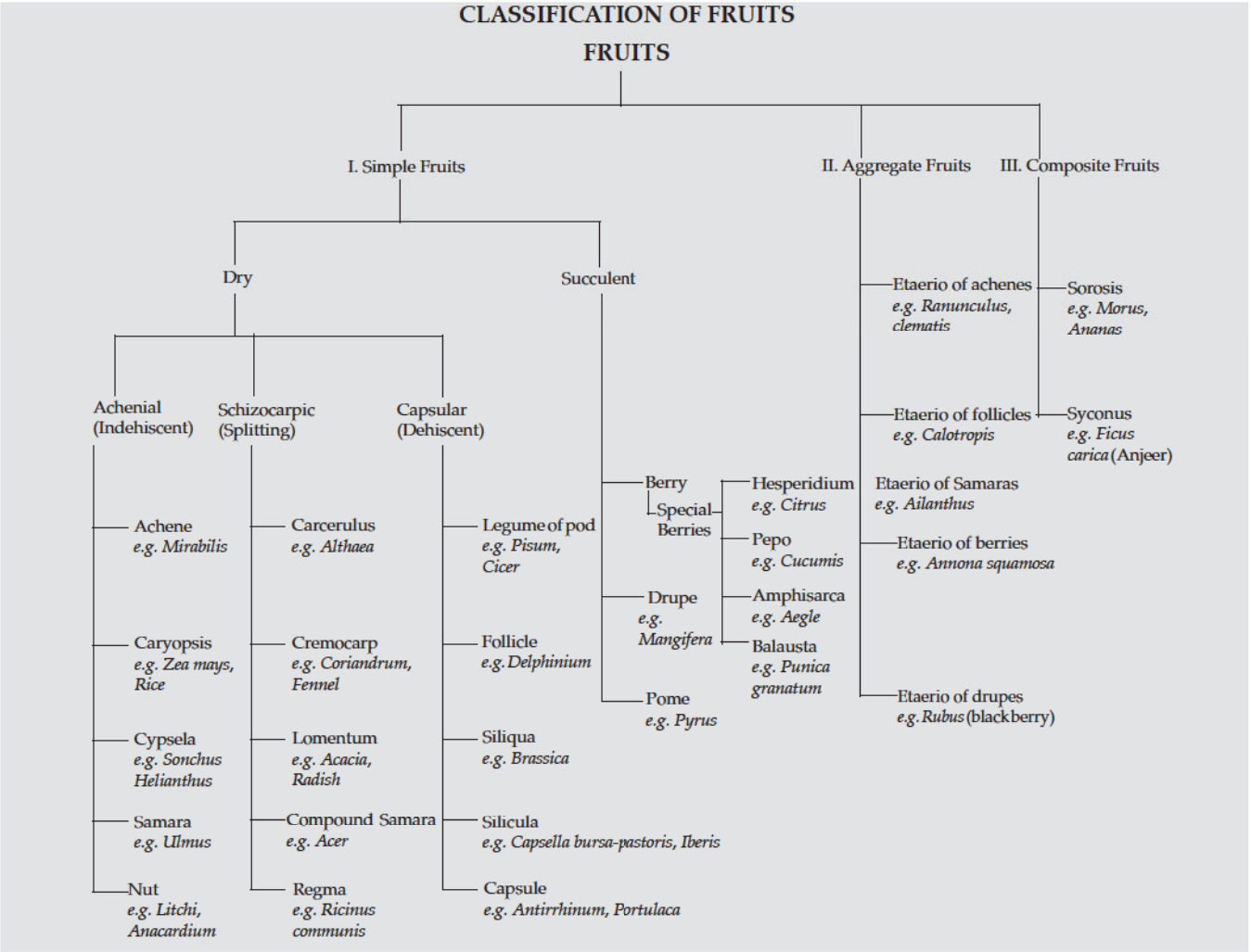


Table 22. Edible parts of fruits.

Botanical Name	Common Name	Type of fruit	Edible Part	Family
Eugenia jambolana	Black plum	Berry	Mesocarp	Myrtaceae
Feronia elephantum	Elephant apple	Amphisarca	Inner endocarp, placentae	Rutaceae
Ficus carica	Fig (Anjeer)	Syconus	Fleshy receptacle and achene	Moraceae
Citrullus vulgaris	Watermelon	Pepo	Mesocarp	Cucurbitaceae
Cocos nucifera	Coconut	Drupe	Endosperm	Palmaceae
Cucumis melo	Muskmelon	Pepo	Mesocarp	Cucurbitaceae
Cucumis sativus	Cucumber	Pepo	Mesocarp	Cucurbitaceae
Aegle mannelos	Wood apple	Amphisarca	Inner endocarp and placentae	Rutaceae
Anacardium occidentale	Cashewnut	Nut	Fleshy aril	Anacardiaceae
Ananas cosmosus	Pineapple	Sorosis	Outer portion of receptacle, bracts, perianth and pericarp fused together	Anacardiaceae

Annona squamosa	Custard-apple	Etaerio of berries	Pericarp	Annonaceae
Arachis hypogea	Groundnut	Legume	Cotyledons	Papilionaceae
Artocarpus integrifolia	Jack fruit	Sorosis	Bracts, perianth	Moraceae
Carica pappaya	Papaya (Papita)	Berry	Mesocarp	Caricaceae
Citrus aurantium	Orange	Hesperidium hairs	Juicy placental	Rutaceae
Citrus medica var. *limonia*	Lemon	Hesperidium	Juicy placental hairs	Rutaceae

Table 23. Differences among Simple, Aggregate and Composite fruits.

Character	Simple fruit	Aggregate fruit	Composite fruit
1. Formation	It is formed from a flower with single ovary.	It is formed from a flower with two or more ovaries.	It is formed from whole inflorescence.
2. Number	Single fruit is borne at one place.	It is a group or etaerio of fruitlets.	Many fruitlets form a composite fruit.
3. Nature	Compact	Can be compact (Strawberry) or loose (*Calotropis*).	Compact.
4. True/False	True or False.	True or False.	False.
5. Example	Pea, Mustard	Strawberry	Pineapple, Jack fruit, Mulberry.

SEED

A seed is a ripened fertilized ovule. It contains an embryonic plant, reserve food and protective coat. A new generation starts with the formation of seed. Embryo (kernel) is the future plant in miniature condition. When the seed is sown in soil a new plant appears from the embryo. In seed, metabolic activities also get suspended to pass over the unfavourable period.

The embryo in the seed is made up of embryonal axis. It contains **radicle** (embryonic root) and **plumule** (embryonic shoot). On the side, one or two embryonic leaves or **cotyledons** are present. In some seeds, food is stored in the endosperm. The seeds which store their food in endosperm are called **endospermic** seed or **albuminous** seed *e.g.* castor been, rubber etc. The seeds which store their food in cotyledons (endosperm absent) are called **non-endospermic** or **exalbuminous** *e.g.* bean, gram etc.

STRUCTURE OF GRAM SEED (DICOT NON-ENDOSPERMIC SEED)

The seeds of gram like those of other legumes are formed within the pod, which is a ripened ovary. The seed is attached to the inside of the pod by the **funiculus** or **seed stalk**. When the seeds are shed, the funiculus breaks off, leaving a prominent scar, the **hilum**. The seed coat has two layers the outer **testa** and inner **tegmen.** Just below the hilum can be seen the micropyle (Fig. 71) and above the hilum is the ridge formed by the **raphe**.

When the seeds are soaked in water, they swell considerably and the seed coats become soft. In this condition the seed coats are easily removed. The entire interior of the seed is occupied by the embryo and chiefly by the two fleshy cotyledons or seed leaves, which may easily be separated. On the side of the seed, opposite the raphe is found the radicle, with its tip directed toward the micropyle, and continuous with it is the hypocotyl. The plumule has differentiated two well-defined leaves which fold over the growing tip. These become the first true leaves of the bean plant on germination.

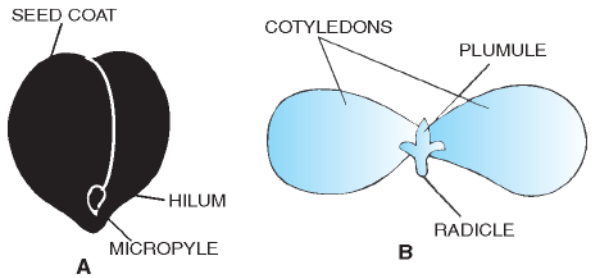


Fig. 71. Structure of Gram Seed, **A.** Entire seed in side view; **B**. Cotyledons of the embryo split open.

In this seed and in all seeds of this type, there is no endosperm, this tissue having already been consumed by the developing embryo. Most of the food of the seed is stored in the two large cotyledons, which in this case never function as true leaves.

STRUCTURE OF CASTOR SEED (DICOT ENDOSPERMIC SEED)

It is broader at one end and pointed at other end with elliptical outline. The colour is mottled dark brown with hard smooth and shining **testa**. **Tegmen is** thin, white and membranous. A soft, white spongy structure called **caruncle** is present at one end of the seed. It is an outgrowth of micropyle. Almost in the middle of flat side of seed a narrow like **raphe** is present (Fig. 72).

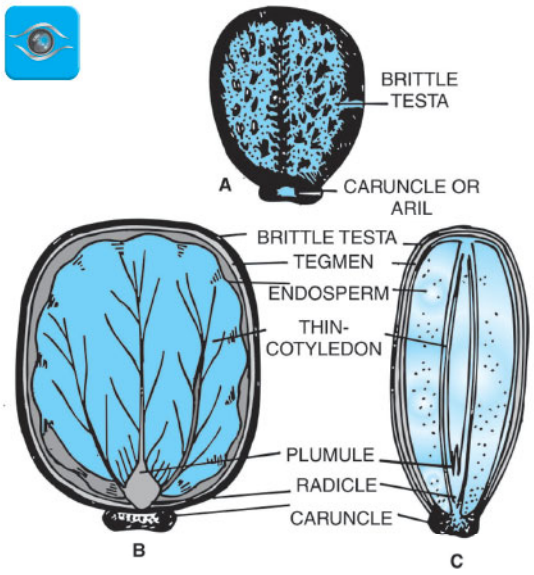


Fig. 72. Castor seed. **A.** External view; **B.** Seed dissected to show cotyledons; **C.** V.S. seed.

There are two **cotyledons** which are thin, oval, papery and veined. **Endosperm** is fleshy in which food is stored. Embedded in the endosperm embryo is present which contains an embryo axis with distinct **radicle and plumule.**

STRUCTURE OF MAIZE GRAIN (MONOCOT, ENDOSPERMIC GRAIN)

It is one seeded fruit called **caryopsis** or grain because pericarp (fruit wall) is fused with testa (Fig. 73). Each grain is made up of following parts:

1. Seed coat. It is the outer brownish layer of the grain. In this, seed and fruit wall are fused together.

2. Endosperm. It comprises the major part of grain and is filled with reserve food. It is composed of two regions: (a) Outer single layered aleurone layer, mainly made up of **aleurone proteins** (b) Inner starchy endosperm. It is separated from embryo by a layer called **epithelium**.

3. Embryo. It contains a single lateral cotyledon called **scutellum** and embryo axis with plumule and radicle are at its two ends. Root cap protects the tip of radicle. Radicle is surrounded by a protective sheath called coleorhiza. Plumule is also protected by a covered sheath known as **coleoptile**.

Seeds as physiological enigma

Seeds have been considered as physiological enigma of living world. They contain a miniature plant, a protective seed coat, reserve food for future growth and little long lived RNA to guide future metabolism and growth.

It is interesting to note that living cell dies if water contents fall below 45-75% but seeds continue to live with 10-15% water content. In seeds, metabolism is suspended animation like in hibernating animals. In seed, all of a sudden growing embryo becomes dormant and stops growth. Food becomes immobile and respiration becomes anaerobic in mature seed. Seeds are able to tolerate high and low temperatures. However at the time of germination seeds destroy chemical inhibitors and start secreting growth hormones.

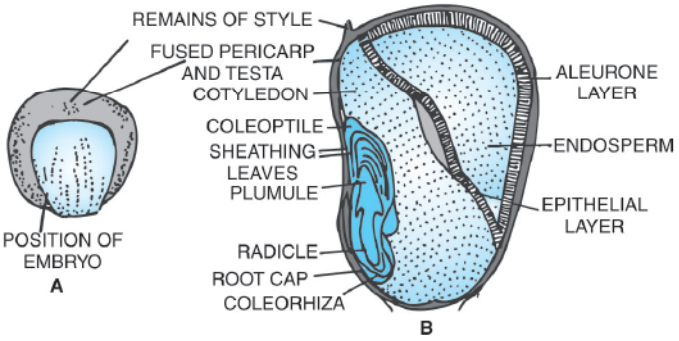


Fig. 73. Maize grain *(Zea mays)* **A.** The entire grain; **B.** L.S. maize grain.

Table 24. Differences between Maize grain and Bean seed.

Characteristics	Maize grain	Bean seed
1. Type of fruit	It is single seeded fruit called the caryopsis.	It is a true seed formed inside a fruit called the pod or a legume. There are many seeds in a pod.
2. Fusion of pericarp	The fruit wall or the pericarp is fused with testa.	The pericarp is free from testa.
3. Seed coats	There is one seed coat which is inseparably fused with pericarp.	There are two seed coats called testa and tegmen. They are fused with each other.
4. Nucellus	The nucellus persists within the seed coat. It is in the form of a single layer of cells.	The nucellus is consumed during seed development.
5. Endosperm	The grain is endospermic.	The seed is non-endospermic.
6. Cotyledon	It has only one cotyledon.	It has two cotyledons.
7. Food storage	The endosperm has a distinct layer called aleurone layer and the starchy endosperm. The aleurone layer is made up of a single layer of cells, whose protoplasm contains aleurone grains. The starchy endosperm is made up of many layers of cells whose protoplasm contains starch grains.	The food is stored in the cotyledons. The cells of the cotyledons are thin walled with their protoplasm filled with protein grains, fats and starch grains.
8. Hilum micropyle and chalaza	The grain has no hilum, micropyle and chalaza on its surface.	The chalaza, hilum and micropyle are clearly visible.

Characteristics	Maize grain	Bean seed
9. Raphe	There is no ridge like raphe.	The raphe is clearly visible.
10. Plumule and radicle	The plumule and radicle are protected by distinct sheaths called the coleoptile and the coleorhiza, respectively.	The plumule and radicle are not covered by any such protective sheaths.
11. Hypocotyl	The hypocotyl is not distinct.	The hypocotyl is distinct.
12. Cotyledons	The cotyledon acts as the absorbing structure that absorb food from the endosperm and transfers it to the embryo.	The cotyledons are merely food storage organs.

ADDITIONAL USEFUL INFORMATIONS ABOUT FRUITS FOR COMPETITIVE EXAMINATIONS

- *Silicula type of fruit resembles siliqua but its breadth and length equal.*
- *In jack fruit (Artocarpus integrifolia) pistillate flowers are developed very close to each other around the rachis.*
- *In lotus, thalamus becomes spongy and some achenes are embedded in it.*
- *Seeds of some plants e.g. orchids are minute, dry and lighter than sand particles.*
- *In fruits of Boerhaavia and Cleome,* ***sticky glands*** *are present which stick to the grazing animals and help in dispersal.*
- ***Lodoicea maldivica*** *(double coconut) is largest fruit and largest seed.*
- *Mango is* ***National fruit*** *of India.*
- *Study of seeds is called* ***spermology.***
- *Juicy endocarpic hair are edible in orange, lime etc.*
- *In* ***spurious or false fruits****, parts other than ovary take part in the formation of fruit.*
- *Bitter taste of some cucurbits is due to presence of* ***tritepenes.***
- *Coconut (drupe), water chestnut (drupe), Peanut, groundnut (lomentaceous pod), betelnut (berry), pinenut (seed) are examples of* ***false nut.***

IMPORTANT PLANT FAMILIES

HOW TO DESCRIBE A FLOWER?

Flower

1. Ebracteate/Bracteate.
2. Pedicellate/Sessile.
3. Ebracteolate/Bracteolate.
4. Actinomorphic/Zygomorphic.
5. Isomery (Bimerous, Trimerous, Pentamerous etc.) or Heteromerous.
6. Bisexual/Unisexual (Staminate or Pistillate.)
7. Hypogynous/Perigynous/Epigynous.
8. Cyclic/Spirocyclic/Acyclic.
9. Colour.
10. Any other character.

Calyx

1. Number of Sepals.
2. Polysepalous/Gamosepalous.
3. Aestivation as Valvate/Twisted/Imbricate/Quincuncial.
4. Shape of Calyx.
5. Colour.
6. Inferior/Superior.

Corolla

1. Number of petals.
2. Polypetalous/Gamopetalous.
3. Aestivation.
4. Shape of corolla as Cruciform/Papilionaceous/Rosaceous/Caryophyllaceous/Infundibuliform/ Rotate/Bilabiate/Tubular/Ligulate.
5. Colour.
6. Smell.
7. Inferior/Superior.
8. Any other character.

Perianth

1. Number of Petals.
2. Polypetalous/Gamopetalous.
3. Sepaloid/Petaloid.
4. Aestivation.
5. Colour.
6. Inferior/Superior.

Androecium

1. Number of Stamens.
2. Polyandrous/Fused (Monadelphous/Diadelphous/Polyadelphous/Syngenesious/Synandrous).
3. Epipetalous/Free Epiphyllous.
4. Number of whorls of stamens. Antipetalous/Alternipetalous/Diplostemonous/Obdiplostemonous.
5. Length of Stamens. Tetradynamous/Didynamous.

6. All stamens fertile/Staminodes/Stamens with lever mechanism.
7. Inserted/Exerted.
8. Bithecous/Monothecous.
9. Basifixed/Dorsifixed/Versatile/Adnate.
10. Introse/Extrose.
11. Superior/Inferior.
12. Any other character.

Gynoecium

1. Number of carpels.
2. Apocarpous/Syncarpous.
3. Superior/Inferior.
4. Number of locules.
5. Number of ovules per locule.
6. Placentation as marginal/Axile/Parietal/Basal/Superficial/Free central.
7. If any nectariferous disc present below the ovary.
8. Style, number and length.
9. Terminal/Lateral/Gynobasic.
10. Stigma number and shape as Capitate/Bilobed/Bifid/Discoid.
11. Sticky/feathery/hairy.
12. Any other character.

Fruit

Simple/Aggregate/Composite.

If **simple.** Legume/Follicle/Siliqua/Silicula/Capsule/Caryopsis/Achene/Cypsela/Nut/Lomentum/Cremocarp/Legume/Pepo/Berry/Amphisarca.

If **aggregate** then write Etaerio or Drupes/Etaerio of follicles/Etaerio of achenes/Etaerio of Berries/Drupe/Pome etc.

If composite then write Sorosis or Syconous.

VERTICAL SECTION, FLORAL FORMULA AND FLORAL DIAGRAM

Vertical Section. It is a section of the flower cut vertically passing through the antero-posterior plane. It gives us a clear picture about the shape of the thalamus and insertion of floral organs on it. It also helps to know about the size, shape and relative position of various floral whorls on the thalamus and thus we can find out whether the flower is hypogynous, perigynous or epigynous. It also shows the placentation in ovary and cohesion or adhesion between the floral parts.

Floral Formula. The floral formula of a flower indicates about its bracteate or ebracteate nature of lower, its sexuality, number of floral parts, free or fused, condition of sepals, petals, stamens and carpels within themselves or with other floral organs of different whorls, superior or inferior position of gynoecium. Following symbols are used to write the floral formula of different flowers :

Bracteate = Br. *Ebracteate* = Ebr.
Bracteolate = Brl. *Ebracteolate* = Ebrl.
Actinomorphic = ⊕ *Zygomorphic* = †
Bisexual flower = ⚥ *Staminate flower* = ♂
Pistillate flower = ♀ *Neuter flower* = N
Epicalyx = Epik. *Calyx* = K
Corolla = C *Perianth* = P
Androecium = A *Gynoecium* = G
Staminodes = Std. *Pistillode* = Ptd.

The actual number of floral parts in a whorl is written at the right foot of the symbol. If the number is exceeding more than 10 or 15, it is indicated with sign of 'α'. If the floral parts of the same types present in two whorls, they are written by sign of plus (+) in between the actual number of parts present in each whorl. Fusion within the same floral organs are shown by writing the number of parts within brackets. Some examples are :

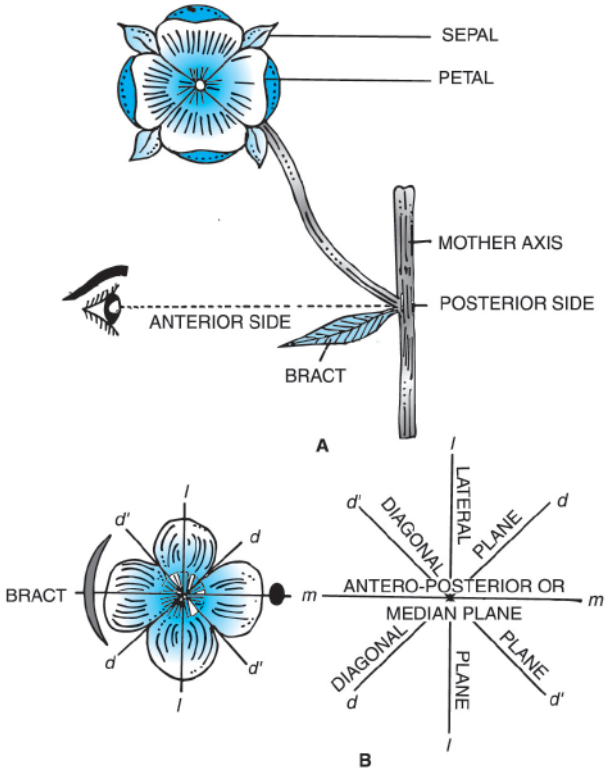


Fig. 74. A. Position of a flower in respect to mother axis, **B.** Top view of flower showing different planes in relation to mother axis (mm – median plane; ll – lateral plane; dd – d'd' – diagonal plane).

K_5 = sepals five free; $K_{(5)}$ = Clayx having five sepals which are fused; K_{2+2} = Sepals 4 arranged in two whorls of two each; $C_{1+2+(2)}$ = Corolla consists of five petals, one in outer whorl, two are in next whorl and free; two are in third whorl and fused; Aα = Androecium consists of many stamens : $A_{(9)+1}$ = Androecium is diadelphous, one group containing nine fused stamens while other group having single free stamen.

The fusion between the floral parts of different floral whorls is shown by an arc which joins the symbols of floral whorls. Superior ovary can be indicated by a bar or line below the number of carpels while inferior condition of carpel is shown by putting the line above the number of carpels. For example:

$\overset{\frown}{C_{(5)}A_5}$ = (Petals five fused in corolla, stamens five free in androecium and epipetalous); $\overset{\frown}{P_{3+3}A_{3+3}}$ = (tepals 6 arranged in two whorls of three each and stamens are also 6 arranged in two whorls, Epiphyllous; $\overset{\frown}{A_{(5)}G_{\underline{2}}}$ = stamens five fused and also fused with carpels; $G = \underline{2}$ (Bicarpellary, apocarpous, superior gynoecium); $G_{(\underline{5})}$ = (Pentacarpellary, syncarpous, superior ovary) and $G_{(2)}$ = (Bicarpellary, syncarpous, inferior gynoecium).

Floral formulae and their explanations of some important flowers

1. *Brassica campestris* **(Mustard or Sarson)**

Ebr ⊕⚥ $K_{2+2}\,C_{x4}\,A_{2+4}\,G_{(\underline{2})}$

Explanation. Ebracteate, actinomorphic, hermaphrodite (bisexual), calyx having four sepals, polysepalous, arranged in two whorls of two each, corolla having four petals, polypetalous, arranged on a arm of a cross ( ) *i.e.* Cruciform, Androecium consists of six stamens present in two whorls, one with two stamens and other with four stamens, Gynoecium-Bicarpellary, syncarpous and superior.

2. *Petunia alba* Ebr ⊕⚥ $K_{(5)}\,C_{(5)}\,\overset{\frown}{A_{(5)}G_{(2)}}$

Explanation. Flower is ebracteate, actinomorphic, hermaphrodite, calyx have five sepals, fused (gamosepalous), corolla having five petals, gamopetalous, androecium consists of five stamens, polyandrous, epipetalous, gynoecium bicarpellary, syncarpous and superior.

FLORAL DIAGRAMS

The floral diagram represents the ground plan of a cross-section of flower bud. The floral diagram shows the number and arrangement of floral parts, symmetry of the flower, regular and irregular flower, fusion among the similar parts (cohesion) and with dissimilar parts (adhesion), sexuality, aestivation of sepals and petals, monothecous and bithecous anthers, extrose or introse, dehiscence, number of loculi and placentation in the ovary, position of odd sepal and presence or absence of bracts and bracteoles (Fig. 76 A and B).

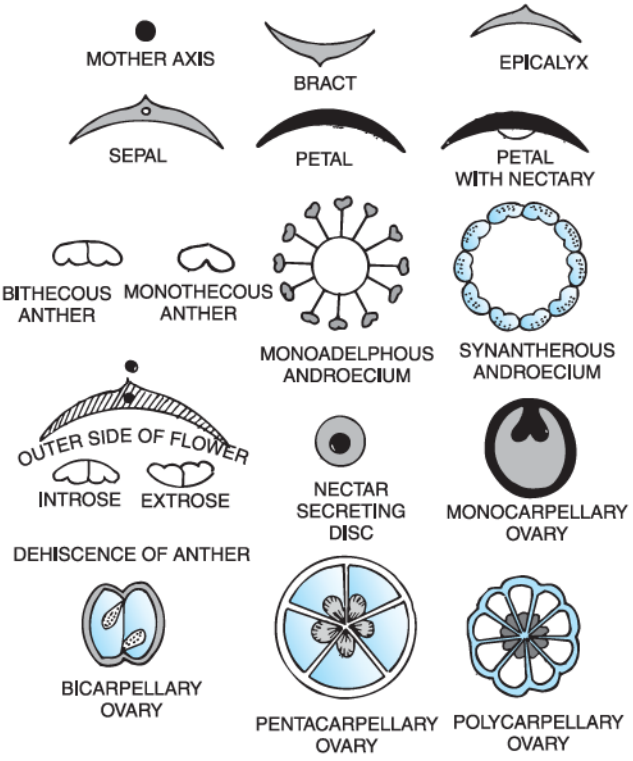


Fig. 75. Symbols.

(i) Symbols for drawing floral diagrams

(ii) How to draw a floral diagram? At first mother axis is shown with a dot. Now find out the position of odd sepal whether it is towards the mother axis (posterior) or on opposite side of mother axis (anterior) and draw it accordingly in respect to mother axis. Normally the odd sepal is posterior in family **Leguminosae** where it is anterior. The petals usually alternates with the sepals.

The floral whorls like epicalyx, calyx, corolla or perianth are drawn respectively in their proper position and exact sequence on the thalamus in respect to the mother axis. While drawing, these whorls show their order of arrangement, overlapping, aestivation and fusion at their margins by joining ends. The anthers are represented by their respective symbols to show monothecous and bithecous conditions. The extrose and introse dehiscence is shown by drawing the sign of anther towards outside and inside respectively. The gynoecium is shown in floral diagram as such seen in transverse section of ovary in respect to mother axis. It can be seen after removing other floral whorls and then by cutting the transverse section of ovary, while flower is attached to the mother axis.

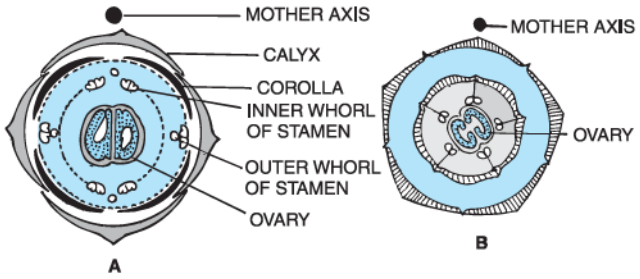


Fig. 76. Floral diagrams : **A.** *Brassica campestris*; **B.** *Petunia alba.*

LILIACEAE

Monocotyledones
Coronarieae

Diagnostic or Distinguishing Characters

1. Flowers trimerous, pentacyclic and hypogynous.

2. Calyx and corolla undifferentiated to form perianth.

3. Tepals 6, in two whorls, odd tepal of outer whorl anterior.

4. Stamen 6, in two whorls of three each, antitepalous and epitepalous.

5. Gynoecium tricarpellary, syncarpous, ovary trilocular and axile placentation.

Distribution and Habit. The family contain 250 genera and 4000 species. Mostly, its members are found in temperate and tropical regions. However, it is cosmopolitan in distribution. Mostly perennial herbs with rhizomes (*Aloe*), bulb (*Allium*), corm (*Colchicum*), shrubs (*Yucca*). Rarely trees (*Xanthorrhoea*), Climbers (*Smilax*, *Asparagus*).

Vegetative Characters

Root. Adventitious and fibrous swollen due to storage of food in *Asparagus*.

Stem. Mostly erect or underground (Rhizome, bulb or corm), Phylloclade or Cladode (*Asparagus*).

Leaves. Radical, Cauline and Ramal. Cauline leaves are simple, alternate, exstipulate, sessile usually with sheathing leaf bases simple venation usually parallel.

Stipular tendrils present in *Smilax*. Tendrillar leaf apex in *Gloriosa*. Leaf apex spiny in *Aloe*, rarely compound.

Floral Characters

Inflorescence. Mostly racemose, sometimes cymose, sometimes solitary.

Flower. Bracteate, pedicellate, actinomorphic, regular, incomplete, bisexual, pentacyclic, trimerous, hypogynous.

Perianth. Six, in two whorls of three each, poly or gamophyllous, sepaloid or petaloid. Odd tepal of outer whorl anterior, inferior.

Androecium. Six, in two whorls of three each, polyandrous, antiphyllous, epiphyllous, anthers dorsifixed or versatile, dithecous, dehiscence longitudinal, introse, inferior.

Gynoecium. Tricarpellary, syncarpous, trilocular, axile placentation, superior, style simple, stigma trilobed.

Fruit. Capsule (*Asphodelus*) or berry (*Asparagus* and *Smilax*).

Floral formula. $\oplus ♀ \quad P_{3+3 \text{ or } (3+3)} A_{3+3} G_{(3)}$

Description of important genera

Asphodelus tenuifolius (Fig. 77)

Floral Characters

Inflorescence. Compound raceme.

Flower. Bracteate, pedicellate, incomplete, actinomorphic, regular, bisexual, hypogynous, trimerous, cyclic, white.

Perianth. Six, in two whorls of three each, polyphyllous or slightly united at the base, odd tepal of outer whorl anterior, each tepal bears a brown mid rib, oblong, petaloid, white, marcescent (wither while attached), inferior.

Androecium. Six, polyandrous, arranged in two whorls of three each, antiphyllous, epihyllous, filaments long and flattened at base, anthers dithecous, dorsifixed, longitudinal dehiscence, introse, inferior.

Gynoecium. Tricarpellary, syncarpous, superior ovary, trilocular, axile placentation, two ovules per locule, style short, stigma trilobed, sticky.

Fruit. Capsule (loculicidal).

F. F. $\oplus ♀ \quad P_{3+3 \text{ or } (3+3)} A_{3+3} G_{(3)}$

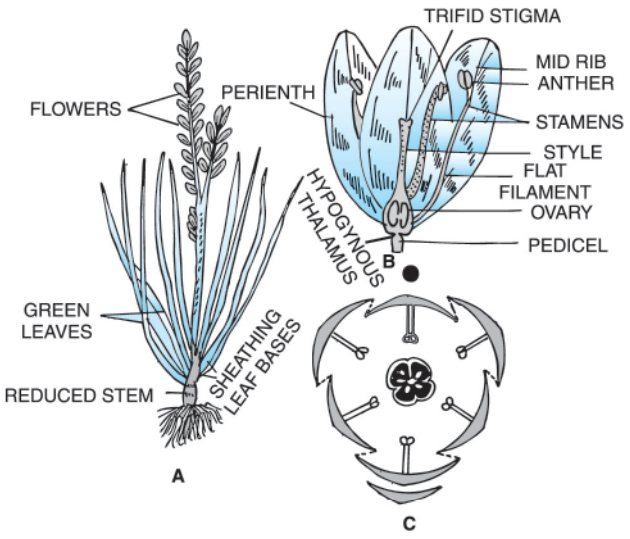


Fig. 77. *Asphodelus tenuifolius* — **A.** A plant; **B.** V. S. Flower; **C.** Floral diagram.

Allium cepa (Fig. 78)

Except the following characters, it resembles with *Asphodelus* :

1. Inflorescence umbellate, cyme at the tip of scape.
2. Flower ebracteate.
3. Green mid rib in each tepal.
4. Perianth gamophyllous.

F. F. $\oplus ♀ \quad P_{3+3 \text{ or } (3+3)} A_{3+3} G_{(3)}$

ECONOMIC IMPORTANCE

1. Food yielding plants. Bulbs of *Allium cepa* (Onion), *A. sativus* (Lassan, Garlic), *A. porrum* (Leek) are used as flavouring agents and food. Young shoots and tubers of *Asparagus* and leaves of *Allium ascolonicum* are cooked.

2. Perfumes. Perfumes are prepared from *Convallaria majalis* (Lily of the valley) and *Hyacinthus orientalis* (Hyacinth).

3. Resins. Resin secreting plants are *Dracaena* and *Xanthorrhea*.

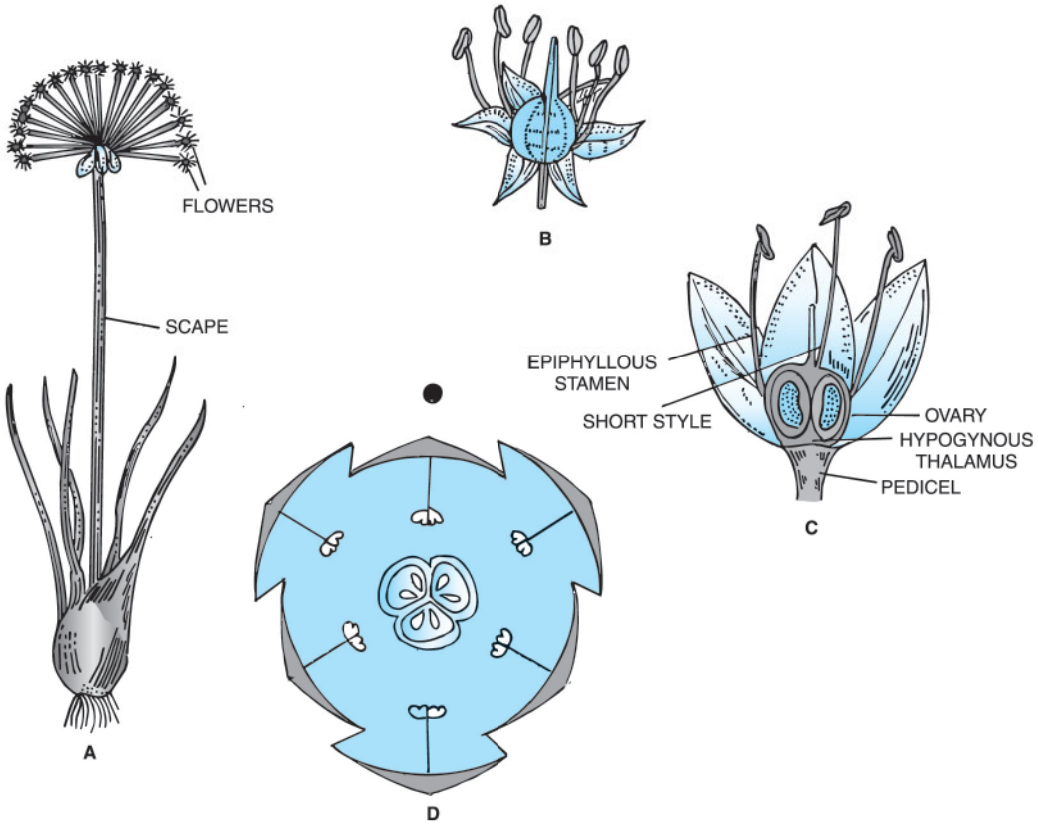


Fig. 78. *Allium cepa* (Family Liliaceae)— **A.** Plant with scape, **B.** A Flower, **C.** V. S. Flower and **D.** Floral diagram.

4. Fibres. Fibres are obtained from plants like *Phormium tenax*, *Agave*, *Yucca* and *Senseviera cylindrica*.

5. Flavouring agents. Onion, garlic, *Smilax microphylla*, *Allium ascalonicum* are used as flavouring agents.

6. Medicinals. Roots of *Smilax* yield Sarasparilla which is used as blood purifier. Garlic has antiseptic and bactericidal characters. Onion (*Allium cepa*) is useful in constipation and diarrhoea. Leaves of *Aloe vera* cure piles, lever troubles and burns and boils. Alkaloid Colchicine is prepared from *Colchicum autumnale* which is extensively used for making the plants polyploid. *Convallaria majalis* is used as cardiac stimulant.

Poison. *Urginea maritima* and root tubers of *Gloriosa superba* are poisonous. They are used for the preparations of raticides.

Ornamentals. *Aloe*, *Asparagus*, *Dracaena*, *Ruscus*, *Smilax*, *Yuccas*, *Hyacinthus*, *Lilies* and *Tulips* are used as ornamentals.

PAPILIONACEAE (FABACEAE)

Dicotyledones
Polypetalae
Calyciflorae
Rosales

Fabaceae family was earlier called **Papilonoideae,** a subfamily of Leguminosae.

Distribution and Habit. It is large family containing more than 600 genera and 13,000 species. It is next to Compositae as far as number of plants is concerned. They are distributed throughout the world. It includes many herbs (*Arachis hypogea*, *Cicer arietinum*) under shrubs (*Indigofera trita*), shrub's (*Cajanas cajan*). Trees (*Sesbania*, *Dalbergia sisso*), climbers and twiners (*Dolichos*, *Pisum sativum*).

Diagnostic or Distinguishing Characters

1. Nodulated roots.
2. Flowers zygomorphic, papilionaceous and perigynous.
3. Calyx 5, gamosepalous.
4. Odd sepal anterior.
5. Corolla 5, **papilionaceous,** 1 + 2 + (2), differentiated into one **standard,** two **alae** and two fused to form **Keel** or **carina.**
6. Petals with descending imbricate aestivation.
7. Androecium usually diadelphous.
8. Gynoecium monocarpellary, unilocular with marginal placentation.
9. Fruit **Legume** or **Lomentum** pod.

Description of important type

***Lathyrus odoratus* (Fig. 79)**

Inflorescence. Cymose cluster or solitary axillary.

Flower. Bracteate, pedicellate, zygomorphic, slightly perigynous, complete, bisexual, colour variable, pentamerous except gynoecium, sweet smelling, papilionaceous.

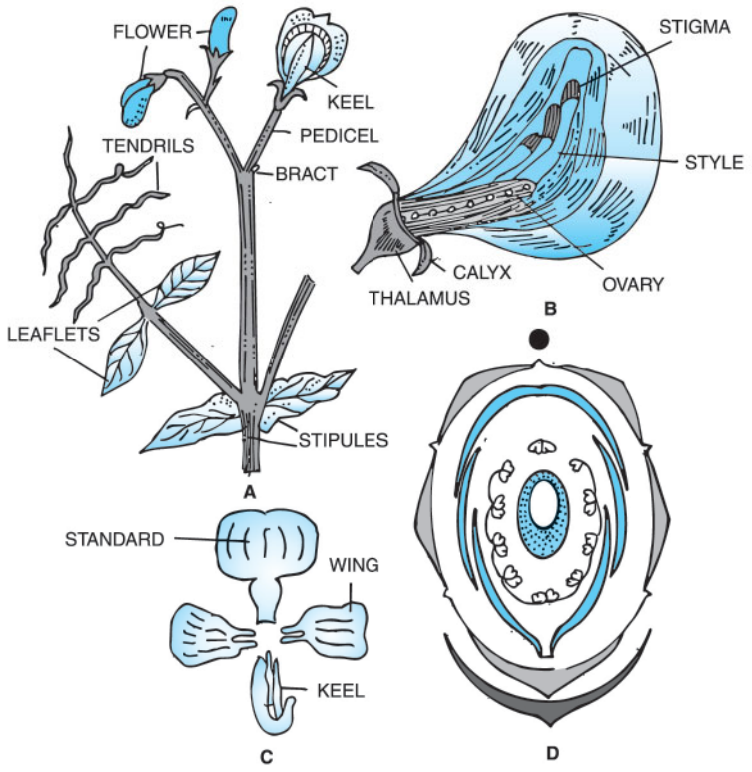


Fig. 79. *Lathyrus odoratus.* **(A)** A flowering branch; **(B)** V.S. Flower; **(C)** Papilionaceous corolla; **(D)** Floral diagram.

Calyx. 5, gamosepalous, campanulate, odd sepal anterior, green, inferior.

Corolla. 5, polypetalous, papilionaceous, large posterior petal is **standard** or **vexillum,** two lateral medium petals are called **alae** or **wings** and two anterior petals fuse to form a boat shaped **Keel** or **Carina** which encloses the essential organs, variously coloured, inferior.

Androecium. Ten, diadelphous, filaments of nine fuse to form a tube which encloses the carpel, tenth posterior stamen is free, longitudinal dehiscence, introse, basifixed, inferior.

Gynoecium. Monocarpellary, superior, unilocular, marginal placentation, present on a short stalk called as gynophore, many ovules in the carpel, style slightly flattened hairy and curved, stigma simple and hairy.

Fruit. A typical legume.

F.F. Br.†⚥ $K_{(5)}\ C_{1+2+(2)}\ A_{1+(9)}\ G_1$

ECONOMIC IMPORTANCE

Food plants. Edible legumens are present in Papilionaceae e.g. *Cicer arietinum* (Gram), *Phaseolus aureus* (Green gram vern. Mung), *Phaseolus mungo* (Black gram, vern. urd), *Phaseolus aconitifolius* (Mat bean vern. Moth), *Glycine max* (Soyabean), *Dolichos lablab* (lablab vern. Sem), *Pisum sativum* (Pea), *Cajanus cajan* (Pigeon pea vern. arhar).

Fodder yielding plants. *Melilotus parviflora* (Senji), *Trifolium alexandrianum* (Barseem), *Medicago sativa* (Lusan) and *Cyamopsis tetragonoloba* (Guar).

Oil. Oil is extracted from the seeds of *Arachis hypogea* (groundnut) and *Glycine max* (Soyabean). Oil is hydrogenated to form vanaspati ghee.

Timber. *Dalbergia sisso* (Shisham or Tahli), *Butea monosperma* (Dhak), *Pterocarpous marsupium* (Bastard Teak).

Green manure. Many plants like *Sesbania*, *Cyamopsis*, *Crotolaria* etc. are used to increase the soil fertility by green manuring and crop rotation.

Fibres. *Crotolaria juncea* (Sunn hemp), *Sesbania* yielding fibres, which are used for making sacks, cordage, nets and tissue paper etc.

Resins and Gums. *Butea monosperma* (Dhak), *Pterocarpus marsupium* (Bastard Teak), *Cyamopsis tetragonoloba* (Guar) are gums and resin secreting plants.

Dyes. *Butea superba* yields red dye, *Indigofera tinctoria* yields 'Neel'. *Butea monosperma* gives yellow dye.

Condiments. *Medicago falcata* (Kasuri Methi), *Trigonella corniculata* (Pirang), *Trigonella graceum* (Fenugred vern. Methi).

Ornamentals. *Lathyrus odoratus*, *Lupinus*, *Clitoria ternataea*, *Sophora* and *Colutea*.

DID YOU KNOW?

- In family **Asteraceae** (Compositae) inflorescence is capitulum. Capitulum may bear only one type of florets (homogamous) or two types of florets i.e. disc florets and ray florets (heterogamous).
- In *Brassica campestris* and *Raphanus sativus* of family Brassicaceae flowers are hexacyclic, bimerous and hypogynous with floral formula :

$$\oplus ⚥ \quad K_{2+C}\, C_{x4}\, A_{2+4}\, G_{(2)}$$

- Stamens are **syngensious** (anthers fused and filaments free) in Compositae family.
- Gynoecium in *Brassica campestris* of family Cruciferae is bicarpellary, syncarpous, superior, unilocular becomes bilocular due to false septum called replum, placentation parietal.
- Florets of *Helianthus annus* are with floral formula :

Disc floret : $\oplus ⚥ \quad K_2$ scales $\overset{\frown}{P_{(5)}A_{(5)}}\ G_{(2)}$

Ray floret : $\dagger ⚥$ or N K_{2-3} scales $C_{(3-5)}\ A_0\ G_{(2)}$ or N

SOLANACEAE

Dicotyledones
Gamopetalae
Bicarpellate
Polymoniales

Diagnostic or Distinguishing characters

1. Aerial parts hairy.

2. Stem usually with bicollateral vascular bundles.

3. Leaves alternate becoming opposite in floral region.

4. Flower actinomorphic, hypogynous.

5. Sepals 5, gamosepalous.

6. Petals 5, gamopetalous.

7. Stamens 5, polyandrous, **alternipetalous** and **epipetalous**.

8. Gynoecium **bicarpellary,** syncarpous, superior, **ovary obliquely placed.**

9. Placentae swollen with **axile placentation.**

10. Fruit berry or capsule.

Distribution and Habit

The family includes 90 genera and 2,200 species. It is cosmopolitan in distribution. The members are found mostly in tropical and sub-tropical regions but represented in temperate regions also. Mostly herbs and shrubs. Rarely trees (*Solanum grandiflorum*). Sometimes climbers also (*Solanum jasminoides*).

Vegetative characters

Root. Branched tap root.

Stem. Herbaceous, erect, branched, hairy or underground tubers in potato. Presence of bicollateral vascular bundles in stem.

Leaves. In vegetative parts alternate and floral regions opposite, simple rarely pinnately divided, always exstipulate.

Floral characters

Inflorescence. Axillary or extra-axillary cyme. Solitary axillary in *Physalis*. Sub–sessile umbellate cyme in *Withania somnifera*. Solitary in *Datura*.

Flower. Actinomorphic, hermaphrodite, sometimes zygomorphic (*Salpiglossis*), complete, hypogynous.

Calyx. 5, gamosepalous, lobed or toothed, persistent, valvate or imbricate aestivation.

Corolla. 5, gamopetalous, lobed, rotate (*Solanum nigrum*), Campanulate (*Atropa*), Infundibuliform (*Petunia*). Aestivation valvate, imbricate or contorted, lobed often folded.

Androecium. 5, alternipetalous, epipetalous, unequal in length, *Salpiglossis* has four fertile stamens, Bithecous, dehiscence longitudinal or by apical pores (*Solanum nigrum*).

Gynoecium. Bicarpellary, syncarpous, superior, obliquely placed, placentae swollen. Becomes 4 celled by appearance of false septum in *Datura*, placentation axile, single terminal style, stigma bilobed.

Fruit. Berry or capsule.

F. F. $\oplus ⚥ \quad K_{(5)}\ \overset{\frown}{C_{(5)}A_5}\ G_{(2)}$

Description of some important genera

Solanum nigrum (Fig. 80)

Inflorescence. Extra axillary cyme.

Flower. Ebracteate, pedicellate, actinomorphic, bisexual, pentamerous except gynoecium, regular, hypogynous, cyclic, white.

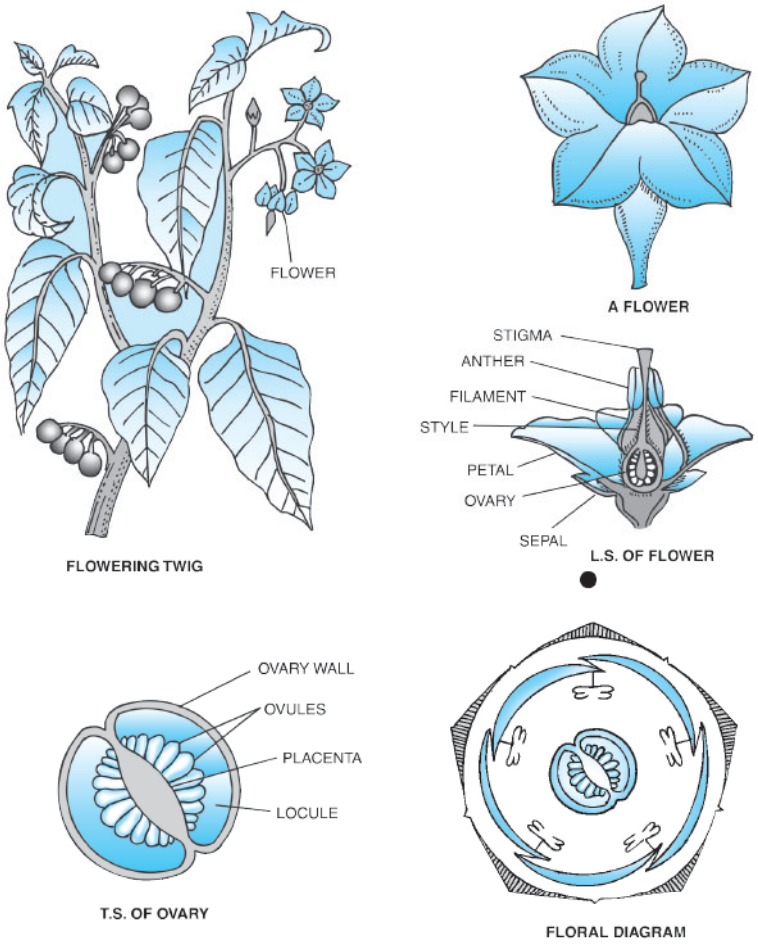


Fig. 80. *Solanum nigrum* (Floral structure).

Calyx. 5, gamosepalous, persistent, valvate, campanulate, green, inferior.

Corolla. 5, gamopetalous, rotate, white, inferior.

Androecium. 5, polyandrous, epipetalous, filaments short, bithecous anthers, basifixed, alternipetalous, dehiscence porous, inferior.

Gynoecium. Bicarpellary, syncarpous, superior, obliquely placed ovary, placentae swollen, axile placentation, bilocular, style long, stigma bilobed, capitate and green.

F. F. Ebr. ⊕⚥ $K_{(5)}\ \overset{\frown}{C_{(5)}A_5}\ G_{(2)}$

Petunia alba (Fig. 81)

Inflorescence. Solitary axillary.

Flower. Bracteate, pedicellate, complete, actinomorphic, hermaphrodite, hypogynous, variously coloured.

Calyx. 5, gamosepalous, penta-partite, companulate, inferior.

Corolla. 5, gamopetalous, infundibuliform, pentafid, inferior.

Androecium. 5, polyandrous, epipetalous, alternate to the petals, basifixed, filaments long, longitudinal dehiscence, inferior.

Gynoecium. Bicarpellary, syncarpous, ovary superior, obliquely placed, swollen placentae, each loculus with numerous ovules, axile placentation, style long, stigma bifid and capitate.

Fruit. A capsule.

Floral Formula. ⊕⚥ $K_{(5)}\ \overset{\frown}{C_{(5)}A_5}\ G_{(2)}$

ECONOMIC IMPORTANCE

1. Food yielding plants. *Solanum tuberosum* (Potato), *S. melongena* (Brinjal), *Capsicum frutescence* var. *grossum* (Simla Mirch), *Physalis pubescens* (Rasbhari), *Lycopersicum esculentum* (Tomato) and *Capsicum annum* (Chillies).

2. Tobacco is obtained from the leaves and branches of *Nicotiana tabacum* and *N. rustica* and used in bidi and cigarettes.

3. *Datura inoxia* and *Hyoscyamus* are narcotics.

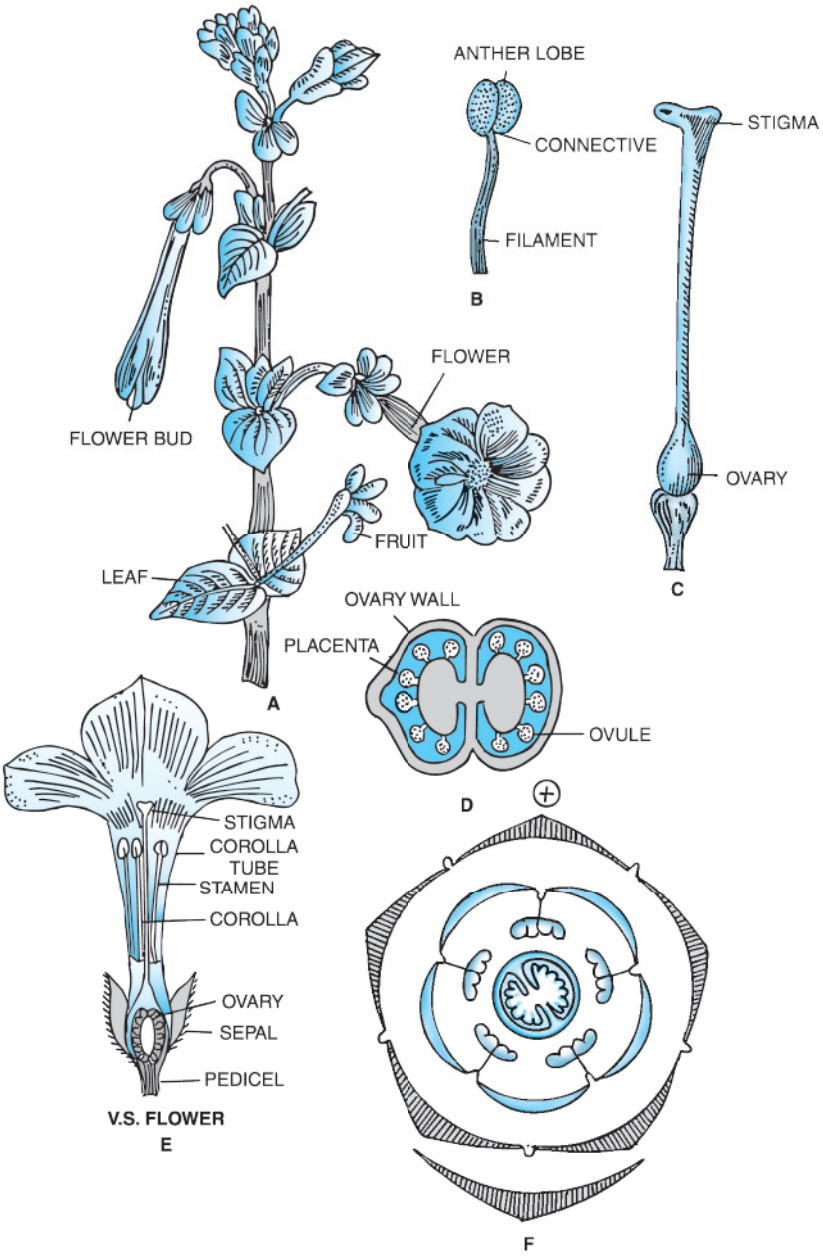


Fig. 81. Solanaceae— *Petunia alba.* **A.** Flowering twig; **B.** Stamen; **C.** Gynoecium; **D.** T.S. of ovary; **E.** L.S. of flower; **F.** Floral diagram.

4. Medicinals. *Atropa belladona* contains **atropine** alkaloid and used in eye testing. It is also used for checking cough, perspiration, dilating the pupils. *Hyoscyamus niger* (Henbane) is a sedative and hypnotic. *Datura*, *Solanum nigrum*, *Withania somnifera* are also medicinal plants. **Nicotine** obtained from tobacco is used as an insecticide. Roots of ashwagandha (*Withania somnifera*) are used medicinally.

5. **Ornamental plants.** *Cestrum nocturnum* (Raat ki rani), *Schizanthus*, *Nicotiana*, *Datura* and *Petunia* are grown in gardens.

PRACTICE PROBLEMS – FAMILIES

6. Describe the sequence of terms, when you are going to describe the gynoecium of any problem.

7. Write about androecium in wheat.

8. Compare the number of stamens, free or fused, number of carpels, free or fused, placentation and number of locules in Liliaceae, Solanaceae and Papilionaceae.

9. Write the floral formulae of :

(a) *Petunia* **(b)** *Lathyrus* **(c)** *Solanum nigrum*

ANSWERS TO PRACTICE PROBLEMS

6. **1.** Number of carples **2.** Apocarpous/Syncarpous **3.** Superior/Inferior **4.** Number of locules **5.** Number of ovules per locule **6.** Placentation **7.** Style, number and length **8.** Terminal/lateral/gynobasic **9.** Stigma number, shape **10.** Sticky/feathery/hairy **11.** Any other character.

7. Three, polyandrous, anthers versatile, bithecous, divaricate, longitudinal dehiscence, inferior.

8.

Character	Liliaceae	Solanaceae	Papilionaceae
1. Number of stamens	6	5	10
2. Free/fused	Polyandrous	Polyandrous	Diadelphous
3. Placentation	Axile	Axile	Marginal
4. Number of carpels	3	5	1
5. Free/fused	Syncarpous	Syncarpous	—
6. Number of locules	Trilocular	Pentalocular	Unilocular

9. (a) *Petunia* ⊕ $\female K_{(5)} \overset{\frown}{C_{(5)}} A_5 G_{(2)}$

(b) *Lathyrus* Br. $\uparrow \female K_{(5)} C_{1+2+(2)} G_1$

(c) *Solanum nigrum* ⊕ $\female K_{(5)} \overset{\frown}{C_{(5)}} A_5 G_{(2)}$

CHAPTER SUMMARY

- The primary root and its branches constitute the **tap root system.**
- When roots arise from parts other than radicle are called **adventitious roots.**
- The root is covered at its apex by thimble-like structure called **root cap.** The **root hairs** absorb water and minerals from the soil.
- Tap roots of carrot, turnip and adventitious roots of sweet potato get **swollen** and **store** food.
- The **stem** bears nodes and internodes.
- **Underground stems** of potato, ginger, turmeric, zamikand, *Colocasia* are modified to store food in them.
- Stem may be modified to form **tendrils**, **thorns** etc.
- A typical **leaf** consists of three main parts: leaf base, petiole and lamina.
- The arrangement of veins and veinlets in the lamina of leaf is termed as **venation.**
- The leaf is said to be **simple**, when its lamina is entire or when incised, the incisions donot touch the midrib.
- **Phyllotaxy** is the pattern of arrangement of leaves on stem or branch.
- Leaves may get modified to perform functions other than photosynthesis.
- The arrangement of flowers on floral axis is termed as **inflorescence.**
- The **flower** is the reproductive unit in the angiosperms.
- Based on the position of calyx, corolla and androecium in respect to the ovary on thalamus, the flowers are described as **hypogynous**, **perigynous** and **epigynous.**
- The mode and arrangement of sepals and petals in floral bud with respect to other members of same whorl is called **aestivation.**
- **Androecium** is composed of stamens. A sterile stamen is called **staminode.**
- **Gynoecium** is the female reproductive part of flower and is made up of one or more carpels.
- The arrangement of ovules within the ovary is called **placentation.**
- The **fruit** is mature, ripened ovary.
- If a fruit is formed without fertilization of ovary, it is called **parthenocarpic fruit**.
- The ovules after fertilisation develop into **seed.**
- Petals in family **Fabaceae** are papilionaceous, and vexillary aestivation.
- Gynoecium in family **Solanaceae** is bicarpellary, syncarpous with swollen placenta and axile placentation.
- In family **Liliaceae**, gynoecium is tricarpellary, syncarpous, superior ovary and with axile placentation.
- The floral features are represented in summarized form as floral diagrams and floral formula.

KEY TERMS

Aestivation : The arrangement of floral parts in bud.
Androecium : The third or male whorl of flower made of stamens.

Adnate	:	Filament running the whole length of anther.
Apocarpous	:	A pistil of two or more carpels which are free.
Annuals	:	The plants which complete their life in one season.
Biennials	:	The plants complete their vegetative growth in one season and bear flowers and fruits in the second season.
Bracteate	:	With bract.
Basifixed	:	Filaments attached to the base of anther.
Catkin	:	A pendent spike of unisexual flowers.
Dorsifixed	:	Filament attached to the back of the anther.
Epiphytes	:	Plants that grow on the stem and branches of other plants, but do not absorb food from them.
Ebracteate	:	Without bracts.
Epigynous	:	Term used for flower when the ovary is inferior and other floral organs arise above it.
Etaerio of drupes	:	An aggregate of drupes.
Free central	:	The ovules are borne on a central column without any septa. The ovary is unilocular.
Ovule	:	The body which encloses embryo sac or female gametophyte and becomes seed after fertilization.
Herbs	:	These are small plants with soft stem.
Hydrophytes	:	The plants that grow in aquatic habitats.
Insectivorous (carnivorous)	:	Plants that capture insects and feed upon them, absorbing only the nitrogenous compounds of their bodies.
Mesophytes	:	The plants that grow in habitats having moderate conditions.
Perennials	:	These plants live for many years.
Parasites	:	Non-green plants that grow upon other living plants and absorb necessary food wholly or partially from them.
Pedicellate	:	Flower with pedicel (stalk).
Raceme	:	A simple elongated indeterminate inflorescence with stalked flowers.
Stele	:	It is the central core of vascular tissue in plants surrounded by pericycle and delimited by endodermis.
Spring wood	:	It is the secondary xylem formed in spring and consists of tracheids and vessels of wider lumen.
Shrubs	:	These are the medium sized plants with a hard and woody stem in which branches arise nearly from the base of the stem.
Tepals	:	One of the separate part of perianth.
Tyloses	:	These are balloon like ingrowths formed in the tracheids and vessels of heart wood from adjacent parenchyma cells.
Tissue	:	A group of similar or dissimilar cells, which have a common origin and perform a common function.
Unilocular	:	With one chamber.
Vexillary	:	Aestivation of petals in Papilionaceae.
Versatile	:	Filament attached to the back of the anther at a point only, so that latter can swing freely.

NCERT FILE *Solved*

NCERT Exercise Questions

1. What is meant by modification of root? What type of modification of root is found in the :
(a) Banyan tree; (b) Turnip; (c) Mangrove trees

Ans. In **modification of roots,** roots may be modified to carry on some special functions. These functions differ from the normal functions assigned to roots *i.e.* storage, assimilation, additional support etc.

(a) Banyan : Prop root

(b) Turnip : Napiform fleshy tap root

(c) Mangrove trees : Pneumatophores or respiratory roots.

(For details, consult the Chapter 5, pages 6-7).

2. Justify the following statements on the basis of external features :

(i) Underground parts of a plant are not always roots.

(ii) Flower is a modified shoot.

Ans. (i) Underground parts of a plant may bear stem like characters. Due to below given reasons, it is considered as stem not root :

(a) Presence of nodes and internodes

(b) Scaly leaves

(c) Axillary and terminal buds

e.g. Rhizome of ginger and banana, corm of *Colocasia* (Kachalu), Bulb of onion and garlic.

(ii) Flower is a modified shoot

(Refer Chapter 5 under heading Flower, pages 39–42).

3. How is pinnately compound leaf different from a palmately compound leaf?

Ans. Refer Table 12.

4. Explain with suitable examples the different types of phyllotaxy.

Ans. Refer Chapter 5 under heading Leaf, pages 23–24.

5. Define the following terms :

(a) Aestivation, (b) Placentation, (c) Actinomorphic, (d) Zygomorphic, (e) Superior ovary, (f) Perigynous flower, (g) Epipetalous stamen.

Ans. (a) **Aestivation.** It is the arrangement of petals in a flower bud in respect to one another.

(b) **Placentation.** It is the mode of arrangement of placentae or ovules bearing cushion of parenchymatous cells within the ovary.

(c) **Actinomorphic.** Here flower can be divided into two similar vertical halves in more than one plane *e.g. Petunia.*

(d) **Zygomorphic.** Here flower can be divided into similar two vertical halves only in one plane *e.g.* pea.

(e) **Superior ovary.** When the various whorls of a flower are arranged below the ovary, the carpel occupies the central position and other floral parts are borne below it, here ovary is said to be **superior** and 'flower is called **hypogynous.**

(f) **Perigynous flower.** If gynoecium is situated in the centre and other parts of the flower are located on the rim of thalamus almost at the same level, it is called perigynous flower *e.g.* plum.

(g) **Epipetalous stemen.** When the stamens are attached to petals, condition is called epipetalous *e.g. Petunia*, Brinjal.

6. Differentiate between :

(a) Racemose and cymose inflorescence

(b) Fibrous root and adventitious root

(c) Apocarpous and syncarpous ovary

Ans. **(a) Racemose and cymose inflorescence**

Refer Table 17, page 36.

(b) Fibrous roots and adventitious roots

Character	Fibrous roots	Adventitious roots
Definition	The roots which develop from base of the stem and fibre like are called fibrous roots.	The roots which appear from parts of plant other than radicle are called adventitious roots.
Example	Wheat	Grass

(b) Apocarpous and syncarpous ovary

Character	Apocarpous ovary	Syncarpous ovary
Definition	Free carpels form apocarpous ovary.	Two or many fused carpels form syncarpous ovary.
Locule	Unilocular	Unilocular or multilocular.
Fruit	Form fruitlet of aggregate type	Form single fruit.
Example	*Ranunculus*	*Petunia, Hibiscus*

7. Draw labelled diagrams of the following :

(i) Gram seed

(ii) V.S. maize grain

Ans. **(i) Gram seed**

Refer Fig. 71, page 52.

(ii) V. S. maize grain

Refer Fig. 73, page 53.

8. Describe modifications of stem with suitable examples.

Ans. Refer Chapter 5 under the heading 'Modification of stems,' pages 13-22.

9. Take one flower each of families Fabaceae and Solanaceae and write its semitechnical description. Also draw their floral diagrams after studying them.

Ans. (i) Give description of flower *Lathyrus odoratus* from Family Fabaceae of Chapter 5, pages 58-59.

(ii) Give description of flower *Solanum nigrum* or *Petunia alba* from Family Solanaceae of Chapter 5, pages 60–62.

10. Describe the various types of placentation found in flowering plants.

Ans. Refer Chapter 5 under the heading 'Placentation,' pages 45–46.

11. What is flower? Describe the parts of a typical angiospermic flower.

Ans. Refer Chapter 5 under the heading 'Parts of a typical flower,' pages 39–45.

12. How do leaf modifications help plants?

Ans. Refer Chapter 5 under the heading 'Leaves with different functions or modifications of leaves,' pages 28–31.

13. Define the term inflorescence. Explain the basis for the different types of inflorescence in flowering plants.

Ans. Refer Chapter 5 under the heading 'Inflorescence,' pages 33–39.

14. Write the floral formula of a actinomorphic, bisexual, hypogynous flower with five united sepals, five free petals, five free stamens and two united carpels with superior ovary and axile placentation.

Ans. $\oplus$ ⚥ $K_{(5)}\, C_5\, A_5\, G_{(2)}$

15. **Describe the arrangement of floral members in relation to their insertion on thalamus.**

Ans. Refer Chapter 5 under the heading 'Relative position of floral parts on the thalamus', page 40.

NCERT Exemplar Problems

A. MULTIPLE CHOICE QUESTIONS

1. **Rearrange the following zones as seen in the root in vertical section and choose the correct option:**
   A. Root hair zone
   B. Zone of meristems
   C. Root cap zone
   D. Zone of maturation
   E. Zone of elongation

Option:
(a) C, B, E, A, D (b) A, B, C, D, E
(c) D, E, A, C, B (d) E, D, C, B, A

2. **In an inflorescence where flowers are borne laterally in an acropetal succession, the position of the youngest floral bud shall be :**
   (a) Proximal (b) Distal
   (c) Intercalary (d) Any where

3. **The mature seeds of plants such as gram and peas, possess no endosperm, because :**
   (a) These plants are not angiosperms
   (b) There is no double fertilization in them
   (c) Endosperm is not formed in them
   (d) Endosperm gets used up by the developing embryo during seed development

4. **Roots developed from parts of the plant other than radicle are called :**
   (a) Tap roots (b) Fibrous roots
   (c) Adventitious roots (d) Nodular roots

5. **Venation is a term used to describe the pattern of arrangement of :**
   (a) Floral organs
   (b) Flower in inflorescence
   (c) Veins and veinlets in a lamina
   (d) All of them

6. **Endosperm a product of double fertilization in angiosperms is absent in the seeds of :**
   (a) Gram (b) Orchids
   (c) Maize (d) Castor

7. **Many pulses of daily use belong to one of the families below (tick the correct answer) :**
   (a) Solanaceae (b) Fabaceae
   (c) Liliaceae (d) Poaceae

8. **The placenta is attached to the developing seed near the :**
   (a) Testa (b) Hilum
   (c) Micropyle (d) Chalaza

9. **Which of the following plants is used to extract the blue dye?**
   (a) *Trifolium* (b) *Indigofera*
   (c) *Lupin* (d) *Cassia*

10. **Match the following and choose correct option:**

Group A	Group B
A. Aleurone layer	i. Without fertilization
B. Parthenocarpic fruit	ii. Nutrition
C. Ovule	iii. Double fertilization
D. Endosperm	iv. Seed

Options:
(a) A-i, B-ii, C-iii, D-iv
(b) A-ii, B-i, C-iv, D-iii
(c) A-iv, B-ii, C-i, D-iii
(d) A-ii, B-iv, C-i, D-iii

ANSWERS

1. (a);	**2.** (b);	**3.** (a);	**4.** (a);	**5.** (c);	**6.** (c);	**7.** (d);	**8.** (a);	**9.** (b);	**10.** (a);
11. (c);	**12.** (c)	**13.** (a);	**14.** (d);	**15.** (a);	**16.** (d);	**17.** (d);	**18.** (a).		

B. VERY SHORT ANSWER TYPE QUESTIONS

1. **Roots obtain oxygen from air in the soil for respiration. In the absence or deficiency of O_2, root growth is restricted or completely stopped. How do the plants growing in marshlands or swamps obtain their O_2 required for root respiration?**

Ans. Plants like *Rhizophora*, which grow in marshy or swamp area bear pneumatophores or respiratory roots. These roots come out of soil, grow vertically and bear respiratory pores (pneumathodes) for respiration.

2. **Write floral formula for a flower which is bisexual; actinomorphic; sepals five, twisted aesitvation, petals five; valvate aestivation; stamens six; ovary tricarpellary, syncarpous, superior, trilocular with axile placentation.**

Ans. $\dagger \overset{\uparrow}{\underset{+}{\circ}} K_{(5)} C_5 A_6 \; G_{(3)}$

3. **In *Opuntia* the stem is modified into a flattened green structure to perform the function of leaves (i.e., photosynthesis). Cite some other examples of modifications of plant parts for the purpose of photosynthesis.**

Ans. Phylloclades of *Meuhlebechia* and *Euphorbia royleana*; cladode of *Asparagus*.

4. In swampy areas like Sunderbans in West Bengal, plants bear special kind of roots called.....

Ans. Pneumatophores

5. In aquatic plants like *Pistia* and *Eichhornia*, the roots are found near.....

Ans. Water surface

6. Reticulate and parallel venation are characteristic of ..... and ..... respectively.

Ans. Dicotyledonous plants, monocotyledonous plants.

7. Which parts of ginger and onion are edible?

Ans. In ginger, edible part is underground stem. In onion, edible part is fleshy scales.

8. In epigynous flower, ovary is situated below the.....

Ans. Remaining parts of thalamus.

9. Add the missing floral organ of the given floral floral formula of Fabaceae:

Br. ⚥ K_5 ____ (A) ..... G.....

Ans. Br. ⚥ $K_{(5)}\ C_1 + 2 + (2)\ A_1 + (9)\ G_1$

10. Name the body part modified for food storage in the following:

Ans. (a) Carrot _____

(b) *Colocasia* _____

(c) Sweet potato _____

(d) *Asparagus* _____

(e) Radish _____

(f) Potato _____

(g) *Dahlia* _____

(h) Turmeric _____

(i) *Gladiolus* _____

(j) Ginger _____

(k) *Portulaca*

Ans.

(a) Carrot	Conical tap root
(b) *Colocasia*	Corm
(c) Sweet potato	Tubercular roots
(d) *Asparagus*	Fasciculated roots
(e) Radish	Fusiform tap roots
(f) Potato	Stem tuber
(g) *Dahlia*	Fasciculated roots
(h) Turmeric	Rhizome
(i) *Gladiolus*	Corm
(j) Ginger	Rhizome
(k) *Portulaca*	Moniliform or beaded roots

C. SHORT ANSWER TYPE QUESTIONS

1. Give two examples of roots that develop from different parts of the angiospermic plant other than radicle.

Ans. **(i)** Prop roots of *Ficus bengalensis* (Banyan)

(ii) Stilt roots of *Zea mays* (Maize) and *Sorghum*.

2. The essential functions of roots are anchorage and absorption of water and minerals in the terrestrial plant. What functions are associated with the roots of aquatic plants. How are roots of aquatic plants and terrestrial plants different?

Ans. **(i)** **Root packets** present at tips of roots in *Pistia* and *Lemna* perform the function of balancers.

(ii) In *Hydrilla* and *Ceratophyllum* roots perform the functions of balancers and anchorage.

(iii) In *Trapa*, the roots turn green and become photosynthetic.

In terrestrial plants, roots mainly perform the functions of anchorage and absorption of minerals and water.

3. Draw diagrams of a typical monocot and dicot leaves to show their venation pattern.

Ans. Refer Fig. 31 'Venation in leaves' of this chapter.

4. A typical angiosperm flower consists of four floral parts. Give the names of floral parts and their arrangements sequentially.

Ans. Refer 'Parts of a typical flower' of this chapter.

5. Given below are a few floral formulae of some well known plants. Draw floral diagrams from these formulae.

(i) ⊕ ♀ $K_{(5)},\ C_{(5)},\ A_{(5)},\ G_{(2)}$

(ii) ⚥ $K_{(5)}\ C_{1+2+(2)}\ A_{(9)+1}G_1$

(iii) ⊕ ♀ $K_5\ C_5\ A_{5+5}G_{(5)}$

Ans. Refer floral diagrams of

(i) Family Solanaceae (*Solanum nigrum)* Fig. 80

(ii) Family Papilionaceae (*Lathyrus odoratus*) Fig. 79

(iii) Family Malvaceae (*Hibiscus rosa-sinensis*)

Floral diagram of *Hibiscus rosa-sinensis*

6. Reticulate venation is found in dicot leaves while in monocot leaves venation is of parallel type. Biology being a 'Science of exceptions' find out any exception to this generalization.

Ans. Exceptions are:

(i) Parallel venation is present in *Ceratophyllum* (a dicot)

(ii) Reticulate venation is found in *Smilax*, *Alocasia* (monocots).

7. You have heard about several insectivorous plants that feed on insects. *Nepenthes* or the pitcher plant is one such example, which usually grows in shallow water or in marsh lands. What part of the plant is modified into a 'pitcher'? How does this modification help the plant for food even though it can photosynthesize like any other green plant?

Ans. Lamina or leaf blade of *Nepenthes* is modified to from a pitcher. The plant is found on nitrogen deficient soil and

is a insectivorous plant. The pitcher engulfs the insects and thus helps in utilising the nitrogen contents of insect.

8. Mango and coconut are 'drupe' type of fruits. In mango fleshy mesocarp is edible. What is the edible part of coconut? What does milk of tender coconut represent?

Ans. In coconut, endosperm is edible.

9. How will you differentiate between central and axile placentation?

Ans. Refer 'Placentation' of the this chapter.

10. Tendrils are found in the following plants. Identify whether they are stem tendrils or leaf tendrils.

a. Cucumber **b. Peas**
c. Pumpkins **d. Grapevine**
e. Watermelons

Ans.
(a) Cucumber — Stem tendril
(b) Peas — Leaf tendril
(c) Pumpkins — Stem tendril
(d) Grapevine — Stem tendril
(e) Watermelon — Stem tendril

11. Why is maize grain usually called as a fruit and not a seed?

Ans. Here fruit is caryopsis where pericarp is fused with seed coat. The maize grains are found attached to thick cob or peduncle.

12. Tendrils of grapevines are homologous to the tendrils of pumpkins but are analogous to that of pea. Justify the above statement.

Ans. In grapevine and pumpkins, tendrils are stem tendrils and resemble in morphology and origin. However, in pea, tendrils are leaf tendrils. Thus they are analogous to tendrils of grapevine and pumpkins (being of different origin).

13. Rhizome of ginger is like the roots of other plants that grow underground. Despite the fact, ginger is a stem not a root. Justify.

Ans. Rhizome of ginger bears nodes and internodes just like stem. It also bears adventitious buds and scale leaves.

14. Differentiate between:

a. Bract and Bracteole b. Pulvinus and Petiole
c. Pedicel and Peduncle d. Spike and Spadix
e. Stamen and Staminoid f. Pollen and Pollenium

Ans.
(a) Bracts : In axil of bracts (small or scaly green structure), flower is borne.
Bracteoles : These are bract like structures borne on the stalk of a flower.

(b) Pulvinus : It represents the leaf base (proximal region) attached to stem.
Petiole : It is stalk of leaf.

(c) Pedicel : Stalk of flower is called pedicel.
Peduncle : Stalk of inflorescence is called peduncle.

(d) Spike : Here sessile flowers are borne in acropetal succession on peduncle e.g. *Adhatoda*.
Spadix : Spadix is like spike and it is enclosed by large bracts called spathe e.g. *Colocasia*.

(e) Pollen : Pollen grains (microspores) of a flower represent the pollen.
Pollenium : Group of pollen grains together constitute pollenium e.g. *Calotropis*.

D. LONG ANSWER TYPE QUESTIONS

1. Distinguish between families Fabaceae, Solanaceae, Liliaceae on the basis of gynoecium characteristics (with figures) Also write economic importance of any one of the above family.

Ans. Refer text of this chapter (Important Plant Families)

2. Describe various stem modifications associated with food storage, climbing and protection.

Ans. Refer 'Aerial Modifications of Stem', Special Modifications of Stem,' Underground Stem' of this chapter.

3. Stolon, offset and rhizome are different forms of stem modifications. How can these modified forms of stem be distinguished from each other?

Ans. Refer 'Sub-aerial Modifications of Stem' and 'Underground Stems' of this chapter.

4. The mode of arrangements of sepals and petals in a flower bud is known as aestivation. Draw the various types of aestivation possible for a typical pentamerous flower.

Ans. Refer 'Aestivation' of this chapter.

5. The arrangements of ovules within the ovary is known as placentation. What does the term placenta refer to? Name and draw various types of placentations in flower seen in T.S. or V.S.

Ans. Refer 'Placentation' of this chapter.

6. 'Sunflower is not a flower'. Explain.

Ans. Sunflower is not a single flower but is an aggreggate of several florets. It is a type of inflorescence called capitulum or racemose head. The main axis of peduncle turns flat called as receptacle. Whorl of bracts called involucre is found at the base of receptacle. It bears two types of florets i.e. central disc florets and peripheral ray florets.

7. How do you distinguish between hypogeal and epigeal germination? What is the role of cotyledon(s) and the endosperm in the germination of seed?

Ans. Refer 'seed' of this chapter.

8. Seeds of some plants germinate immediately after shedding from the plants while in other plants they require a period of rest before germination. The later phenomenon is called dormancy. Give the reasons for seed dormancy and some methods to break it.

Ans. Reasons for seed dormancy :
(i) Impermeable seed coat to water e.g. *Chanopodium*.
(ii) Impermeable seed coat to chemicals e.g *Xanthium*.
(iii) Hard seed coat e.g. *Capsella*.
(iv) Presence of inhibitors like ABA, phenolics etc.
(v) Due to presence of excess of salts e.g. *Atriplex*.
(vi) Immature embryos.

Methods for breaking dormancy:
(i) In alimentary canal some seeds get treated with digestive enzymes.

(ii) To give time for ripening of embryo.
(iii) Development of growth hormones like auxins, cytokinins, gibberellins etc.
(iv) By treating them with heat, light, oxidation etc.
(v) By mechanical scarification.
(vi) By chemical scarification.
(vii) By giving chilling treatment.

HOTS Higher Order Thinking Skills & Brain Twisting

QUESTIONS WITH ANSWERS

Very Short Answer Questions *One mark each*

1. What are twiners?
Ans. Twiners are weak stemmed plants, where stem coils around support e.g. Railway creeper.
2. What is thorn? How can you tell it is modified stem?
Ans. Thorn is hard, sharp, pointed structure and provides protection from grazing animals. It also reduces the rate of transpiration. Its stem like characters are : (i) Axillary (ii) Bears small leaves in *Duranta*.
3. What is coleorhiza ?
Ans. It is a sheath like covering on radicle-root cap region of embryo in monocot seeds.
4. What is pepo? Give one example.
Ans. It is a special trilocular, inferior ovary. In this case, exocarp does not separate from mesocarp e.g. *Cucurbita*.
5. Name the smallest angiospermic plant.
Ans. *Wolffia arrhiza*
6. What are achenial fruits ?
Ans. They are simple, single seeded dry and indehiscent fruits.
7. What is gynobasic style?
Ans. It appears from the base of ovary e.g. *Ocimum*.
8. What do you mean by syngenesious condition?
Ans. When in stamens anthers are fused and filaments are free e.g. sunflower.
9. What is tigellum ?
Ans. Tigellum is the axis of embryo which bears radicle at one end, plumule at the other end and cotyledons in between.

Short Answer Questions *Two marks each*

1. Name the inflorescence where it is found hanging ?
Ans. It is catkin e.g. mulberry and popular.
2. Differentiate between apocarpous and syncarpous ovary.
Ans. Apocarpous bears free carpels e.g. Lotus, rose. Syncarpous ovary bears fused carpels e.g. *Petunia, Hibiscus*.
3. Name the type of stem tendril found in *Passiflora, Luffa, Vitis.*
Ans. *Passiflora*-Axillary, *Luffa* –Extra-axillary; *Vitis*-Apical.
4. What is zygomorphic flower ?
Ans. A flower, which can be cut into two equal halves only in one plane e.g. Pea.
5. Which type of phyllotaxy is present in *Alstonia* ?
Ans. In this case, number of leaves appear from a node, it is called whorled.
6. What is perigynous ovary?
Ans. Here gynoecium of flower is borne in the centre and other parts of flower are present on the rim of thalamus almost at same level.
7. Which type of gynoecium is present in family Liliaceae ?
Ans. Tricarpellary, syncarpous, trilocular with axile placentation.

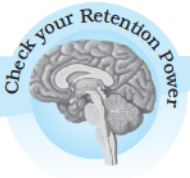
Short Answer Questions *Three marks each*

1. Describe the distinguishing characters of family Solanceae.
2. Describe the distinguishing characters of family Fabaceae.

3. Draw the diagrams of different types of aestivation.
4. Describe three types of modified leaves.
5. Write short note on rhizome.
6. Write the economic importance of family Fabaceae.
7. Stolon, offset and bulb are different forms of stem modification. How can these modified forms of stem can be distinguished from each other?

Long Answer Questions *Five marks each*

1. How do various leaf modifications help plants ?
2. Describe the modification of stem with suitable examples and diagrams.
3. Discuss the various types of placentations found in angiosperms.
4. Describe the various types of phyllotaxy.
5. Which type of modification of root is found in following plants:
   (i) Turnip (ii) Banyan tree (iii) *Rhizophora* (iv) *Dahlia* (v) *Cuscuta*
6. How is pinnately compound leaf different from palmately compound leaf.
7. Discuss the following types of inflorescence :
   (a) Cyathium (b) Verticillaster (c) Hypanthodium



QUICK MEMORY TEST

A. Say True or False

Write "True" or "False".

1. The shape of carrot root is napiform.
2. Rhizomes occur in plants such as ginger and banana.
3. Thorns are found in plants like *Citrus* and *Bougainvillea.*
4. Veins are irregularly distributed to form network in parallel venation.
5. *Dionaea* is rootless aquatic herb which form leaf bladders to trap insect.
6. Biennial are plants which complete their life cycle in two years.
7. Guard cells play little role in the proper functioning of stomata.
8. Heart wood is softer than the sap wood and not durable.
9. Branches of root arise from pericycle.
10. If both male and female flowers are produced on separate plants, it is called monoecious.
11. *Drosera* obtains proteins by digesting the insects.
12. The well developed root system of *Pistia* serves to absorb water.
13. The leaf of *Citrus* represents a simple leaf.
14. *Utricularia* is provided with a trap or mechanism to store the food material.
15. *Wolffia* is the smallest flowering plant.
16. Lotus is the national flower of India.
17. In family Solanaceae placentation is basal.
18. *Datura* belongs to family Solanaceae.
19. Gynoecium is bicarpellary, unilocular with basal placentation in family Compositae.
20. Flowers are trimerous and hypogynous in family Papilionaceae.
21. Odd sepal is anterior in family Papilionaceae.
22. Pulses belong to family Papilionaceae.
23. Fruit is cypsela in family Gramineae.
24. *Allium cepa* belongs to family Solanaceae.
25. In *Brassica,* tetradynamous type of stamens are present.
26. Number of petals is five in cruciform corolla.

B. Complete the missing links

Fill the following sentences with the suitable word :

1. ..... firmly fix the plant to the soil.
2. Primary roots develop from the ..... .
3. The roots arising from any part of the plant other than the radicle are called ..... .
4. When the root is swollen in the middle and tapers gradually at both ends, it is called ..... .
5. Turnip is an example of ..... root.
6. Sweet potato is an example of ..... tuberous root.
7. When the adventitious roots have swollen regions at frequent intervals, it is called ..... .
8. The time taken for the development of two adjacent leaves is called ..... index.
9. *Trapa* possesses ..... roots.
10. The root tip is covered by a .....
11. The shoot system is developed from ..... of the embryo.
12. The nodes and internodes are .....in the stem.
13. Stem creeping on the ground, having long internodes are called .....
14. A thin, spirally coiled branch, very sensitive to contact is called .....
15. Rhizome is a modification of underground .....
16. Potato is a modification of underground ..... and is called .....
17. Hard, straight and pointed structures present in the axil of a leaf are called .....
18. A phylloclade with one or two internodes only is called a .....
19. Plants which live for many years are called.....
20. The terminal bud in ..... branching becomes modified into a flower.

C. Choose the correct alternative

1. Petals come to each other but do not overlap in **valvate/imbricate** aestivation.
2. In brinjal, stamens are **epiphyllous/epipetalous.**
3. In *Ocimum*, flowers are **actinomorphic/zygomorphic.**
4. Monocot seeds bear one large shield shaped cotyledon called as **scutellum/coleoptile.**
5. In China **rose/Kaner**, alternate phyllotaxy is present.
6. Climbing roots are present in ***Pothos/Zea mays.***

Answers QUICK MEMORY TEST

A. Say True or False

1. False; **2.** True; **3.** True; **4.** False; **5.** False. *Utricularia* is a rootless herb which forms leaf bladders to trap insects; **6.** False Biennials are plants which remain vegetative in first season and become reproductive in the next season; **7.** False. Guard cells play major role in opening and closing of stomata; **8.** False. Heart wood is more stronger than sap wood as it is lignified; **9.** True; **10.** False. If male and female flowers occur on different plants, it is called dioecious; **11.** True; **12.** False. Well developed root system in *Pistia* helps in floating; **13.** False The leaf of citrus is compound leaf as main leaflet is terminal while tow lateral leaflets have become reduced. This has been confirmed from its anatomy also; **14.** False. In *Utricularia*, trap door mechanism is meant for entrapping insects; **15.** True; **16.** True; **17.** False; **18.** True; **19.** True; **20.** False; **21.** True; **22.** True; **23.** False; **24.** False; **25.** True; **26.** False.

B. Complete the missing links

1. roots; **2.** radicle; **3.** Adventitious roots; **4.** fusiform; **5.** napiform; **6.** reproductive adventitious; **7.** fasciculated; **8.** Plastochorn; **9.** assimilatory; **10.** root cap or root-pocket; **11.** Plumule; **12.** Present; **13.** runners; **14. tendrils**; **15.** stem; **16.** stem, tuber; **17.** thorn; **18.** cladode; **19.** perennials; **20.** cymose.

C. Choose the correct alternative

1. Valvate; **2.** Epipetalous; **3.** Zygomorphic; **4.** Scutellum; **5.** China rose; **6.** *Pothos*.

REVISION EXERCISES

Very Short Answer Questions

One mark each

1. *Cuscuta* develops roots to penetrate the host tissue and obtain nutrition. What are these roots called?
2. What is heterophylly?
3. Give the scientific name of the insectivorous plant of north eastern part of India which is now an endangered species.
4. Name two plants that show alternate phyllotaxy.
5. What is cladode?
6. How is *Cuscuta* adapted for its heterotrophic nutrition?
7. Which same plant part has transformed into the following different modifications : (i) Tendril pumpkin (ii) Thorn of *Citrus*.
8. Which part of the plant leaf is modified to form spines of *Acacia* and the sheath covering the leaf of *Ficus elastica?*
9. Give one example of heterogamous type of capitulum.
10. Which type of inflorescence is present in corinader?
11. Name the outer covering of seed.
12. Give one example of non-endospermic dicot seed.
13. Name two plants showing dichasial cyme type of inflorescence.
14. What is pomology?
15. Give one example where epigynous type of flower is present.
16. Give the technical term for the kind of pollination carried out by birds.
17. Name a cultivated plant in which neither fruits nor seeds are formed.
18. Which type of placentation is present in *Lathyrus*.
19. What do you mean by modification of root? What type of modification of roots are found in :
    (a) Carrot **(b)** Turnip **(c)** *Dahlia*
20. Name the edible part of mango, apple, banana, coconut.
21. Name a family with alternipetalous and epipetalous stamens.
22. To which family *Asparagus* belongs?
23. Write the floral formula of *Solanum nigrum*.
24. Name a family with diadelphous condition.
25. Write the type of placentation in *Brassica* and *Allium*.
26. How many stamens are present in family Liliaceae?
27. Name a flower with inferior ovary.
28. Write the botanical name of rice.
29. In which family odd sepal is anterior?
30. Which type of corolla is present in family Brassicaceae?
31. Give the botanical name of potato. *(Himachal Board 2005)*
32. Give the botanical name of peepal. *(Himachal Board 2005)*
33. Give the botanical name of carrot. *(Himachal Board 2005)*
34. The arrangement of flowers on floral axis is called..... .
    (i) Aestivation **(ii)** Phyllotaxy **(iii)** Placentation **(iv)** Inflorescence *(Kerala Board 2017)*

ANSWERS

1. Haustoria
2. Heterophily is the occurrence of two different types of leaves.
   Example. In *Ranunculus aquatilis* leaves in water are dissected and outside the water, they are entire.
3. *Nepenthes*.
4. Mango and *Hibiscus*.
5. Phylloclade with one node is called cladode.
6. Plant of *Cuscuta* is never green and consequently, it has no power to prepare its own food and it gets the food supply from host plant on which parasites through parasitic or haustorial roots.
7. Stem (axillary bud).
8. Leaf petiole.
9. Sunflower
10. Compound umbel
11. Testa **12.** Pea **13.** *Dianthus*, *Silene* **14.** Study of fruits and their cultivation
15. Sunflower
16. Ornithophily
17. Sugarcane
18. Marginal.
19. When roots are modified to carry out some additional functions, they represent modification of roots.
    (a) Prop roots; **(b)** Napiform; **(c)** Pneumatophores; **(d)** Fascicled or fasciculated roots.
20. Edible parts : **Mango** – Mesocarp; **Apple** – Fleshy pericarp; **Banana** – Mesocarp and endocarp; **Coconut** – Endosperm.
21. Solanaceae
22. Liliaceae
23. $\oplus \quad K_{(5)}\, C_{(5)} A_5\, G_{(2)}$
24. Papilionaceae
25. *Brassica* - Parietal, *Allium* - Axile
26. Six

27. Sunflower
28. *Oryza sativa*
29. Papilionaceae
30. Cruciform
31. *Solanum tuberosum*
32. *Ficus religiosa*
33. *Daucus carota*
34. (IV), Inflorescence

Short Answer Questions — *Two marks each*

1. What is typical achene?
2. Describe grain type of fruit.
3. Describe hypanthodium type of inflorescence.
4. Describe the androecium in Fabaceae.
5. Write any two important diagnostic characters of family Liliaceae.
6. Name the food yielding plants of Liliaceae.
7. Describe the corolla in family Fabaceae (Papilionaceae).
8. Name few pulses.
9. Write about corolla of *Petunia.*
10. Name few food yielding plants of family Solanaceae.
11. Name any four ornamentals of family Solanaceae.
12. Potato is a stem and sweet potato is a root. Justify the statement. *(Himachal Board 2005)*
13. What is the difference between simple leaf and compound leaf? *(Himachal Board 2005)*
14. What is phyllotaxy? Name two types of phyllotaxy. *(Himachal Board 2005)*
15. How can you differentiate actinomorphic from zygomorphic flower ? *(Kerala Board 2005)*

ANSWERS

1. **Typical Achene.** Small, one-seeded; seed attached to pericarp at one point only; pericarp readily separable from seed coat *(Clematis, Ranunculus).*
2. **Grain or Caryopsis.** Small, one-seeded; seed coat fused to pericarp over its entire surface (corn, wheat, oats, rye and barley.)
3. **Hypanthodium.** In this case fleshy receptacle forms a hollow cavity which is more or less pear shaped with a narrow apical opening guarded by scales. Canal is lined by downwardly poined hairs. Internally the receptacle bears male flowers towards the pore and female flowers towards the base e.g. Peepal, Banyan etc.
4. Ten, diadelphous, filaments of nine fused to form a tube, tenth posterior stamen free, introse, basifixed, inferior.
5. **(a)** Tepals 6, in two whorls of 3 each, odd tepal of outer whorl anterior.
   (b) Stamens 6, in two whorls of 3 each, antitepalous and epiphyllus.
6. *Allium cepa* (onion), *A. sativum* (Garlic), *A. porrum* (Leek) and *Asparagus.*
7. Five, polypetalous, papilionaceous, large posterior petal is **standard,** two lateral petals are called **keel** and two anterior petals fused to form **keel** inferior.
8. *Cicer arietinum* (Gram), *Phaseolus aureus* (Mung), *Glycine max* (Soyabean), *Cajanus cagan* (Arhar).
9. Five, gamopetalous, valvate aestivation, infundibuliform (*Petunia*), rotate (*Solanum nigrum*, inferior)
10. *Solanum tuberosum* (potato), *Solanum melongena* (Brinjal), *Lycopersicon esculentum* (tomato).
11. *Cestrum* (Raat ki rani), *Schizanthus, Datura, Nicotiana* and *Petunia.*
12. Potato is underground tuber (stem) on which nodes and internodes with adventitious buds (in eyes) are present. Scale leaves are absent. Sweet potato is underground modified tubercled adventitious root which is non-green and swollen. Scale leaves, nodes, internodes are absent.
13. Simple leaf is one in which there is a single lamina and which is not divided completely into distinct leaf-lets. A leaf is called compound when incision of leaf lamina goes down to the mid rib (rachis) or to the petiole so that leaf is broken down into number of segments called leaf-lets.
14. Arrangement and distribution of leaves on stem is called phyllotaxy.
    (a) Alternate; **(b)** Opposite **(c)** Whorled.
15.

Character	Actinomorphic flower	Zygomorphic flower
1. **Division**	Divisible into two equal halves by any vertical plane.	Divisible into two equal halves by one vertical plane only.
2. **Regular/Irregular**	Regular	Partially irregular.
3. **Symmetry**	Radial	Bilateral

Short Answer Questions — *Three marks each*

1. Differentiate between spadix and catkin.
2. Describe parietal type of placentation.
3. What is placentation? Describe basal type of placentation.

4. Describe the following terms : (a) Cruciform corolla, (b) Tetradynamous stamens (c) Adelphous.
5. What is perigyny?
6. Name different types of fleshy fruits and give one example each.
7. On the basis of external appearance of plant, how will you distinguish between dicot and monocot plants?
8. What is a true fruit? Write the significance of fruit formation in plants.
9. Discuss the gynoecium in Solanaceae.
10. Describe the androecium in Liliaceae.
11. Write about corolla in Papilionaceae (Fabaceae).
12. Draw the floral diagram of *Solanum nigrum.*
13. Define the following terms :
    (a) Simple fruits (b) Aggregate fruits (c) Composite fruits (d) Phyllotaxy
    (e) Inferior ovary (f) Epigynous flower (g) Imparipinnate leaves. ***(NCERT)***
14. Write the economic importance of family Liliaceae.
15. Differentiate between phylloclade and cladode. ***(Himachal Board 2005)***
16. Give differences between stem and root. ***(Himachal Board 2005)***
17. What is inflorescence? What type of inflorescence is present in *Coriander?* ***(Himachal Board 2005)***

Long Answer Questions

Five marks each

1. Describe in brief the various types of placentations found in flowering plants.
2. What is aestivation? Describe its various types found in petals.
3. Write an account of various types of fruits.
4. What do you understand by dispersal of fruits and seeds? Describe the role of various agents in it.
5. To which family pulses belong? Write the economic importance of that family.
6. Compare the androecium and gynoecium in Solanaceae and Liliaceae.
7. Draw the floral diagrams of :
    (i) *Petunia* (ii) *Asphodelus*
8. Compare the corolla of Solanaceae and Papilionaceae.
9. Write the floral formulae of the following :
    (i) *Allium cepa* **(ii)** *Solanum nigrum* **(iii)** *Lathyrus* **(iv)** *Petunia*
10. Write brief notes on the following :
    (i) Runner (b) Sucker (c) Stolon ***(Himachal Board 2005)***
11. Give brief notes of the following :
    (i) Napiform roots (b) Conical roots (c) Parasitic roots ***(Himachal Board 2005)***

COMPETITION FILE OBJECTIVE TYPE QUESTIONS

A. MULTIPLE CHOICE QUESTIONS (MCQs):

(From AIPMT & Other Competitive Examinations)

1. The photosynthetic or assimilatory roots are observed in :
    (a) Banyan (b) *Vanda* (c) *Cuscuta* (d) *Tinospora* ***(J and K 2009)***
2. Sunflower belongs to the family :
    (a) Liliaceae (b) Asteraceae (c) Cruciferae (d) Peaty soil ***(DUMET 2009)***
3. Which of the following is a rootless aquatic plant, which portion of the leaf forms a tiny sac for trapping insects?
    (a) *Nepenthes* (b) *Drosera* (c) *Utricularia* (d) *Dionaea* ***(DUMET 2009)***
4. In which plant, the fruit is drupe, seed coat is thin, embryo is inconspicuous and endosperm is edible?
    (a) Groundnut (b) Wheat (c) Apple (d) Coconut ***(DUMET 2009)***
5. In a monoecious plant :
    (a) Male and female sex organs are on different individuals
    (b) Male and female gametes are of two morphologically distinct types
    (c) Male and female sex organs are on same individual
    (d) All the stamens are fused to form one unit ***(DUMET 2009)***
6. Pineapple fruit develops from :
    (a) Unilocular polycarpellary flower (b) Multipistillate syncarpous flower
    (c) Multilocular monocarpellary flower (d) A cluster of compactly born flowers on an axis
    (DUMET 2009)
7. In some seeds, reminants of nucellus are also persistent. This residual persistent nucellus is the :
    (a) Pericarp (b) Perisperm (c) Chalazosperm (d) Mesosperm ***(AIIMS 2009)***

8. In root nodules of legumes, leghaemoglobin is important because :
(a) It transports oxygen to the root nodule (b) It acts as oxygen scavanger
(c) It provides energy to the nitrogen fixing bacterium (d) It acts as catalyst in transamination **(*DUMET 2009*)**

9. A fibrous root system is excellent for :
(a) Food storage (b) Nitrogen fixation
(c) Absorbing water from deeper layers of soil (d) Providing good anchorage for the plant **(*DUMET 2009*)**

10. If a primary root continues to grow, the type of root system will be known as :
(a) Secondary (b) Fibrous (c) Tap (d) Stilt **(*DUMET 2009*)**

11. A horizontal underground stem is a :
(a) Corm (b) Phylloclade (c) Rhizome (d) Rhizoid **(*DUMET 2009*)**

12. Wheat is which of the following types of fruit of ?
(a) Berry (b) Nut (c) Caryopsis (d) Legume (pod) **(*DUMET 2009*)**

13. Root cap is absent in :
(a) Mesophytes (b) Hydrophytes (c) Epiphytes (d) Xerophytes **(*UP-CPMT 2009*)**

14. Zygomorphic condition can be represented as :
(a) ⊕ (b) † (c) P (d) G **(*UP-CPMT 2009*)**

15. An example of false fruit is :
(a) Apple (b) Banana (c) Grapes (d) Mango **(*UP-CPMT 2009*)**

16. Lady's finger belongs to family :
(a) Malvaceae (b) Cucurbitaceae (c) Liliaceae (d) Brassicaceae **(*UP-CPMT 2009*)**

17. Glumes represent :
(a) Bracts (b) Sepals (c) Petals (d) Stamens **(*UP-CPMT 2009*)**

18. Smallest flower is :
(a) *Wolffia* (b) Lotus (c) *Rafflesia* (d) *Brassica* **(*UP-CPMT 2009*)**

19. The floral formula ⊕ ♂♀ $K_{(5)}C_{(5)}A_5\ G_{(2)}$ is that of :
(a) Tulip (b) Soybean (c) Sunnhemp (d) Tobacco **(*CBSE 2009*)**

20. An example of axile placentation is :
(a) Argemone (b) Dianthus (c) Lemon (d) Marigold **(*CBSE 2009*)**

21. A fruit developed from hypanthodium inflorescence is called :
(a) Hesperidium (b) Sorosis (c) Syconus (d) Caryopsis **(*CBSE 2009*)**

22. Type of aestivation shown by *Pisum* is :
(a) Imbricate (b) Vexillary (c) Twisted (d) Quincuncial **(*J & K 2011*)**

23. Study the following statements and select the correct option :
(A) Buds are present in the axil of leaflets of the compound leaf.
(B) Pulvinus leaf-base is present in some leguminous plants.
(C) In *Alstonia*, the petioles expand, become green and synthesize food.
(D) Opposite phyllotaxy is seen in guava.
(a) (B) and (D) are correct but (A) and (C) are wrong. (b) (A) and (C) are correct but (B) and (D) are wrong.
(c) (A) and (D) are correct but (B) and (C) are wrong. (d) (B), (C) and (D) are correct but (A) is wrong.
(e) (A) and (B) are correct but (C) and (D) are wrong. **(*Kerala 2011*)**

24. Select the correct match :
(a) *Colchicum autumnale* – Solanaceae
(b) *Petunia* – Solanaceae
(c) *Gloriosa* – Fabaceae
(d) *Trifolium* – Liliaceae
(e) *Sesbania* – Solanaceae **(*Kerala 2011*)**

25. Match the following and choose the correct combination from the options given below :

	Column I (Placentation Types)		Column II (Represented in)
A	Basal	1.	*Dianthus*
B	Free Central	2.	Pea
C	Parietal	3.	Lemon
D	Axile	4.	Marigold
E	Marginal	5.	*Argemone*

(a) A-1, B-2, C-3, D-4, E-5 (b) A-2, B-3, C-4, D-5, E-1 (c) A-4, B-1, C-5, D-3, E-2
(d) A-4, B-3, C-5, D-1, E-2 (e) A-5, B-4, C-3, D-2, E-1 **(*Kerala 2011*)**

26. The plant having monadelphous stamens and axile placentation is :
(a) Lemon (b) Pea (c) Tomato
(d) Cucumber (e) China rose **(*Kerala 2011*)**

27. Which of the following plants have long slender and coiled stem tendrils developed from axillary buds?
(a) Grapevine and pumpkins (b) Australian *Acacia* and watermelon
(c) *Bougainvillea* and cucumber (d) Strawberry and grapevine
(e) *Alstonia* and pumpkins **(*Kerala 2011*)**

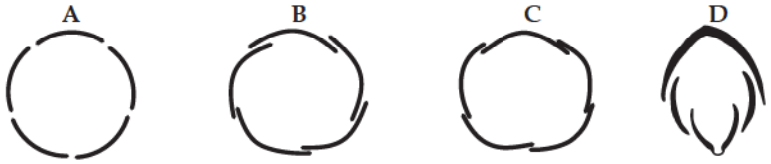
28. Select the correct statements :
(A) From the region of elongation, some of the epidermal cells for root hairs.
(B) Pneumatophores are seen in *Rhizophora.*
(C) Adventitious roots are seen in the banyan tree.
(D) Maize and sugarcane have prop roots
(a) A and D (b) A, C and D (c) C and D
(d) B and C (e) A, B and D **(*Kerala 2011*)**

29. Match the following and select the correct combination from the options given below :

	Column I (Stem Modifications)		Column II (Found in)
A	Underground stem	1.	*Euphorbia*
B	Stem tendril	2.	*Opuntia*
C	Stem thorns	3.	Potato
D	Flattened stem	4.	*Citrus*
E	Fleshy cylindrical stem	5.	Cucumber

(a) A-1, B-2, C-3, D-5, E-4 (b) A-2, B-3, C-4, D-5, E-1 (c) A-3, B-4, C-5, D-1, E-2
(d) A-3, B-5, C-4, D-2, E-1 (e) A-5, B-3, C-4, D-1, E-2 **(*Kerala 2011*)**

30. The following diagrams represent the types of aestivation in corolla. Identify the correct combination of labelling :



(a) A-Valvate, B-Twisted, C-Vexillary, D-Imbricate (b) A-Valvate, B-Vexillary, C-Twisted, D-Imbricate
(c) A-Vexillary, B-Imbricate, C-Twisted, D-Valvate (d) A-Valvate, B-Imbricate, C-Twisted, D-Vexillary
(e) A-Valvate, B-Twisted, C-Imbricate, D-Vexillary **(*Kerala 2011*)**

31. Which of the following plants has the floral characters like zygomorphic flower, vexillary aestivation, diadelphous androecium and marginal placentation?
(a) *Pisum* (b) *Belladona* (c) Brinjal
(d) *Asparagus* (e) *Aloe* **(*Kerala 2011*)**

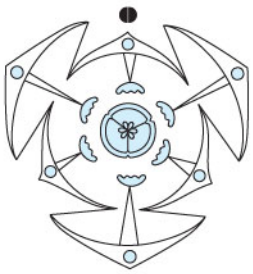
32. From the options given below, find out the correct floral formula for a flower having the following characters namely actinomorphic, bisexual, five united sepals, five united petals, stamens five and epipetalous, bicarpellary, syncarpous with superior ovary.
(a) $\oplus \, ♀ \, K_{(5)}C_{(5)}A_5 \, \underline{G}_{(2)}$ (b) $\oplus \, ♀ \, K_{(5)}\overline{C_{(5)}A_{(5)}} \, \underline{G}_{(2)}$ (c) $\oplus \, ♀ \, K_{(5)}C_{(5)}A_{(5)} \, \underline{G}_{(2)}$
(d) $\oplus \, ♀ \, K_{(5)}\overline{C_{(5)}A_{(5)}} \, \overline{G}_{(2)}$ (e) $\oplus \, ♀ \, K_{(5)}\overline{C_{(5)}A_{(5)}} \, G_{(2)}$ **(*Kerala 2011*)**

33. Whorled simple leaves with reticulate venation are present in :
(a) China rose (b) *Alstonia* (c) *Calotropis* (d) Neem **(*CBSE 2011*)**

34. Which one of the following diagrams represents the placentation in *Dianthus?*

(a) (b) (c) (d) **(*CBSE 2011*)**

35. Plants having the given floral diagram are:



(a) Leguminous
(b) Dicots
(c) Medicinal and perennial
(d) Having pinnately compound leaves *(AIPMT 2012)*

36. Which one of the following organisms is correctly matched with its three characteristics?
(a) Pea: C_3 pathway, endospermic seed, vexillary aestivation
(b) Tomato: twisted aestivation, axile placentation, berry
(c) Onion: bulb, imbricate aestivation, axile placentation
(d) Maize: C_3 pathway, closed vascular bundles, scutellum *(AIPMT 2012)*

37. How many plants in the list given below have marginal placentation?
Mustard, Gram, Tulip, *Asparagus*, Arhar, Sun hemp, Chilli, *Colchicum*, Onion, Moong, Pea, Tobacco, Lupin.
(a) Four (b) Five (c) Two (d) Three *(AIPMT 2012)*

38. Which of the following is correct arrangement of corolla in family Papilionaceae:
(a) $C_{1+(2)-2}$ (b) $C_{1+2+(2)}$ (c) C_{1+2+2} (d) $\widehat{C_{(5)}\,A_{(5)}}$ *(BHU 2012)*

39. Colchicine is obtained from which of the following families?
(a) Poaceae (b) Brassicaceae (c) Malvaceae (d) Liliaceae *(AFMC 2012)*

40. Obliquely placed ovary and swollen placenta is associated with which of the following families?
(a) Asteraceae (b) Solanaceae (c) Brassicaceae (d) Malvaceae *(J & K 2012)*

41. On the basis of position of the ovary, mustard plants are:
(a) Hypogynous (b) Perigynous (c) Epigynous (d) Zygomorphic *(J & K 2012)*

42. The flower of *Calotropis* has which of the following aestivations?
(a) Twisted (b) Imbricate (c) Valvate (d) Vexillary *(J & K 2012)*

43. Match the following and choose the correct combination from the options given:

Column-I (Family)	**Column-II (Androecium formula)**
(A) Brassicaceae	1. A_{3+3}
(B) Fabaceae	2. $A_{(5)}$
(C) Solanaceae	3. $A_{(9)+1}$
(D) Liliaceae	4. A_{2+4}

(a) A-4, B-3, C-2, D-1 (b) A-1, B-2, C-3, D-4 (c) A-2, B-3, C-4, D-1 (d) A-3, B-4, C-1, D-2
(e) A-4, B-3, C-1, D-2 *(Kerala 2012)*

44. Find out the pairs, which are correctly matched with respect to aestivation of petals.
I. Valvate — *Calotropis* II. Twisted — Bean
III. Imbricate — *Cassia* IV. Vexillary — China rose
(a) I and IV (b) I and II (c) I and III (d) III and IV (e) II and III *(Kerala 2012)*

45. Find out the correctly matched pair.

Placentation types	**Represented in**
(a) Marginal	— Tomato
(b) Axile	— Pea
(c) Parietal	— Primrose
(d) Free central	— *Argemone*
(e) Basal	— Marigold

(Kerala 2012)

46. When the margins of sepals or petals overlap one another without any particular direction, the condition is termed as :
(a) Vexillary (b) Imbricate (c) Twisted (d) Valvate *(AIPMT 2014)*

47. Placenta and pericarp are both edible portions in:
(a) Apple (b) Banana (c) Tomato (d) Potato *(AIPMT 2014)*

48. Which one of the following statements is not correct ?
(a) The seed in grasses is not endospermic
(b) Mango is a parthenocarpic fruit
(c) A proteinaceous aleurone layer is present in maize grain
(d) A sterile pistil is called a staminode *(AIPMT 2014)*

49. Non-albuminous seed is produced in :
(a) Maize (b) Castor (c) Wheat (d) Pea. ***(AIPMT 2014)***

50. An example of edible underground stem is :
(a) Carrot (b) Groundnut (c) Sweet potato (d) Potato. ***(AIPMT 2014)***

51. An aggregate fruit is one which develops from :
(a) Multicarpellary syncarpous gynoecium (b) Multicarpellary apocarpus gynoecium
(c) Complete inflorescence (d) Multicarpellary superior ovary ***(AIPMT 2014)***

52. Aleurone layer is present in:
(a) Virus infected plant cell (b) Pathogenic fungi (c) Bacterial biofilm (d) Seed ***(Odisha 2013)***

53. Multicostate divergent reticulate venation is seen in ..... leaf:
(a) *Zizyphus* (b) Bamboo (c) Castor (d) Manog ***(Maharashtra 2014)***

54. Fruit of fig is :
(a) Sorosis (b) Syconus (c) Drupe (d) Berry ***(Bihar CECE 2015)***

55. Which one of the following is non-endospermic seed ?
(a) Maize (b) Coconut (c) Groundnut (d) Wheat ***(Maharashtra CET 2015)***

56. Which one of the following is not a natural method of vegetative propagation?
(a) Runner (b) Foliar buds (c) Stem tuber (d) Grafting ***(Maharashtra CET 2015)***

57. A true fruit is one in which the fleshy part of fruit derived from the :
(a) Thalamus (b) Ovary (c) Inflorescence axis (d) Apocarpous gynoecium ***(COMEDK 2015)***

58. The wheat grain has an embryo with one large shield shaped cotyledon known as :
(a) Scutellum (b) Coleoptile (c) Epiblast (d) Coleorhiza ***(AIPMT 2015)***

59. Coconut water from a tender coconut is :
(a) Innermost layer of seed coat (b) Degenerated nucellus
(c) Immature embryo (d) Free nuclear endosperm ***(AIPMT 2015)***

60. The monocotyledonous seed consists of one large and shield shaped cotyledon known as a/an :
(a) Coleoptile (b) Scutellum (c) Aleurone layer (d) Coleorhiza ***(J and K 2015)***

61. The term polyadelphous is related to:
(a) Gynoecium (b) Androecium (c) Corolla (d) Calyx ***(NEET-II 2016)***

62. Free central placentation is found in:
(a) *Dianthus* (b) *Argemone* (c) *Brassica* (d) *Citrus* ***(NEET-II 2016)***

63. Which one of the following is not a stem modification?
(a) Pitcher of *Nepenthes* (b) Thorns of *Citrus*
(c) Tendrils of *Cucumber* (d) Flattened structures of *Opuntia* ***(NEET-II 2016)***

64. Stems modified into flat green organs performing the function of leaves are known as:
(a) Cladodes (b) Phyllodes (c) Phylloclades (d) Scales ***(NEET-I 2016)***

65. Tricarpellary, syncarpous gynoecium is found in flowers of:
(a) Liliaceae (b) Solanaceae (c) Fabaceae (d) Poaceae ***(NEET-I 2016)***

66. In *Bougainvillea*, thorns are the modification of:
(a) Adventitious root (b) Stem (c) Leaf (d) Stipules ***(NEET- 2017)***

67. Plants which produce characteristics like pneumatophores and show vivipary belong to:
(a) Halophytes (b) Psammophytes (c) Hydrophytes (d) Mesophytes ***(NEET- 2017)***

68. Coconut fruit is :
(a) Berry (b) Nut (c) Capsule (d) Drupe ***(NEET- 2017)***

69. The morphological nature of the edible part of coconut is :
(a) Cotyledon (b) Endosperm (c) Pericarp (d) Perisperm ***(NEET- 2017)***

70. Sweet potato is a modified:
(a) Adventitious root (b) Tap root (c) Stem (d) Rhizome ***(NEET- 2018)***

71. Pneumatophores occur in:
(a) Free-floating hydrophytes (b) Carnivorous plants
(c) Halophytes (d) Submerged hydrophytes ***(NEET- 2018)***

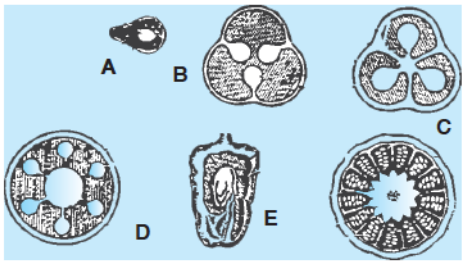
72. Which part of poppy plant is used to obtain the drug "Smack"?
(a) Latex (b) Roots (c) Flowers (d) Leaves *(NEET- 2018)*

ANSWERS

1. (d);	2. (b);	3. (c);	4. (d);	5. (c);	6. (d);	7. (b);	8. (b);	9. (d);	10. (c);
11. (c);	12. (c);	13. (b);	14. (b);	15. (a);	16. (a);	17. (a);	18. (a);	19. (d);	20. (c);
21. (c);	22. (a);	23. (a);	24. (b);	25. (c);	26. (e);	27. (a);	28. (d);	29. (d);	30. (e);
31. (a);	32. (b);	33. (b);	34. (d);	35. (c);	36. (c);	37. (c)	38. (b);	39. (d);	40. (b);
41. (a);	42. (c);	43. (a);	44. (c);	45. (e)	46. (b);	47. (c);	48. (b);	49. (d);	50. (d);
51. (b);	52. (d);	53. (c);	54. (b);	55. (c);	56. (d);	57. (b);	58. (a);	59. (d);	60. (b);
61. (b);	62. (a);	63. (a);	64. (b);	65. (a);	66. (b);	67. (a);	68. (d);	69. (b);	70. (a);
71. (c);	72. (a).								

B. CBSE - PMT (MAIN EXAMINATION) QUESTIONS :

1. **(a)** Identify the placentation shown in following figures :
(b) Write the type of placentation found in following plants.
(A) Mustard **(B)** *Dianthus* **(C)** Pea
(D) Marigold **(E)** Lemon **(F)** *Argemone* *(CBSE 2005)*



Ans. 1. **(a)** **(A)** Marginal, **(B)** Parietal, **(C)** Axile,
(D) Free central, **(E)** Basal, **(F)** Superficial.
(b) **(A)** Parietal, **(B)** Free central, **(C)** Marginal,
(D) Basal, **(E)** Superficial, **(F)** Parietal.

2. **(a)** Name the type of fruit in the bold word and mention the character asked in the question :
Aggregate, Composite, Drupe, Pome, Pepo, Berry, Cypsela, Schizocarp, Follicle, Hesperidium
(i) Coconut, Edible part; **(ii)** Orange, Placentation; **(iii)** Coriander, Inflorescence.
(b) Name the type of inflorescence in the bold words and mention the character asked in the question :
Umble, Corymb, Verticillaster, Capitulum, Spike, Cyathium, Capitate, Spadix
(i) Marigold, Fruit; **(ii)** Euphorbia, Fruit. *(CBSE 2006)*

Ans. **(a)** **(i)** Coconut : Type of fruit : **Drupe;** Edible part : **Endosperm**
(ii) Orange : **Hesperidium;** Placentation : **Axile**
(iii) Coriander : **Cremocarp;** inflorescence : **Compound umbel**
(b) **(i)** Marigold : **Capitulum;** Fruit : ***Cypsela***
(ii) *Euphorbia* : **Cyathium;** Fruit : **Regma** (Schizocarpic).

3. **Inflorescence, placentation, fruits**

Flower	Inflorescence	Placentation	Fruits
(i) Sunflower			
(ii) Coriander			
(iii) Wheat			
(iv) Pea			
(v) Mustard			

Ans.

Flower	Inflorescence	Placentation	Fruits
(i) Sunflower	Capitulum	Basal	Cypsella
(ii) Coriander	Compound umbel	Basal	Cremocarp
(iii) Wheat	Spike of spikelet	Basal	Caryopsis
(iv) Pea	Axillary cyme	Marginal	Caryopsis
(v) Mustard	Raceme	Parietal	Siliqua

4. Differentiate between :

(a) Culm and Caudex. **(b)** Hypanthodium and Cyathium. ***(CBSE 2007)***

Ans. (i)

Culm	Caudex
Unbranched stems without leaf crown.	Unbranched stem with leaves crowned at the apex.
Nodes and internodes are extremely clear.	Node and internodes are not extremely clear.
Internode are hollow *e.g., Bambusa.*	Internode are not hollow *e.g.,* Datepalm.

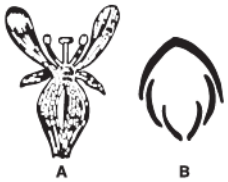
(ii)

Hypanthodium	Cyathium
The receptacle is flask shaped and fleshy.	The receptacle is cup shaped and never fleshy.
The peduncle forms the receptacle.	The involucre form the receptacle.
The flowers are completely enclosed in the receptacle *e.g., Ficus,* Fig.	The flowers are generally exposed on the opening of the receptacle *e.g., Euphorbia.*

5. Carefully study the following figures and answer the following questions :

(i) What is **A** epigynous or hypogynous ovary. Give reason.

(ii) What is the aestivation in **B**? In which of the following, it is found?



(CBSE 2007)

Ans. (i) Epigynous. Ovary lies below the other floral parts and thalamus is fused with ovary wall.

(ii) Descending imbricate. Example – Pea.

6. Complete the following statements (i) to (iv) by picking up the correct alternative from those given in the box below:

Candituft, Guava, Peach, *Nymphaea*, Cycades, *Cucurbita*, *Marsilea*, *Isoetes*, *Vallisneria*, Nandadevi, Karnataka, Nilgiri, Maharashtra

(i) The inferior ovary is found in ..... and .....

(ii) Rooted hydrophyte with floating leaves plants are ..... a pteridophyte and ..... an angiosperm.

(iii) Dioecious plants are ..... gymnosperm and ..... an angiosperm.

(iv) The first biosphere reserve is ..... and is situated in three states ....., Kerala and Tamilnadu. ***(CBSE 2008)***

Ans. (i) *Cucurbita*, Guava **(ii)** *Marselia*, *Nymphaea* **(iii)** Cycades, *Vallisneria* **(iv)** Nilgiri, Karnataka

7. Identify the given diagram and select suitable example for this diagram out of the given examples :

Primula, *Dianthus*, Hollyhock, Sunflower, Pea, *Citrus* ***(CBSE 2009)***

Ans. Free central placentation;
Examples – *Primula*, *Dianthus*

8. Write placentation, inflorescence and type of fruits of the following :

(a) *Pionsettia* **(b)** Merigold **(c)** Onion **(d)** Tomato **(e)** Radish

Ans.

Plant	Placentation	Inflorescence	Fruit
(a) *Pionsettia*	Axile	Cyathium	Regma
(b) Merigold	Basal	Capitulum	Cypsela
(c) Onion	Axile	Corymbose or cymose umbel	Capsule
(d) Tomato	Axile	Cymose	Berry
(e) Radish	Parietal	Compound raceme	Siliqua

9. (a) There are no flowers in banyan tree. Is it so? Comment on it.

(b) Differentiate between phyllode and phylloclade. Give one example of each : ***(CBSE 2009)***

Ans. (a) Banyan tree has hypanthodium inflorescence in which the receptacle becomes pear shaped and contains a hollow central cavity and a hairy opening called ostiole at their anterior side. The hollow cavity bears many male flowers at the ostiole side and female flowers at the basal side. Between male flowers and female flowers, gall flowers (sterile female flowers) are also present.

(b) Refer table 14

C. MATCHING TYPE QUESTIONS :

I. Match the terms in Column A with suitable terms in Column B :

Column A	Column B
(i) Spadix	(a) *Brassica*
(ii) *Morus*	(b) Legume
(iii) Replum	(c) Cremocarp
(iv) Litchi	(d) Bean
(v) Dehiscence from both the sutures	(e) Cypsela
(vi) Drupe	(f) Pea
(vii) Mericarp	(g) Catkin
(viii) Dicot—non endospermic seed	(h) Incomplete
(ix) Sunflower	(i) Gynobasic
(x) *Salvia*	(j) Coconut
(xi) Marginal placentation	(k) *Colocasia*
(xii) Flower with perianth, stamens and carpels	(l) *Brassica*
	(m) Nut

II. Match the terms in Column A with suitable terms in Column B :

Column A	Column B
(i) Perianth	(a) Lemma
(ii) Gramineae	(b) Wheat
(iii) Awn is extension of mid rib	(c) *Asphodelus*
(iv) Caryopsis	(d) Ovary obliquely placed
(v) Liliaceae	(e) Compositae
(vi) Epiphyllous	(f) Spikelet
(vii) Solanaceae	(g) Trimerous
(viii) Syngenesious	(h) Tepals

ANSWERS

I. (i) (k); (ii) (g); (iii) (a); (iv) (m); (v) (b); (vi) (j); (vii) (c); (viii) (d); (ix) (e); (x) (i); (xi) (f); (xii) (h).

II. (i) (h); (ii) (f); (iii) (a); (iv) (b); (v) (g); (vi) (c); (vii) (d); (viii) (e)

D. ASSERTION TYPE QUESTIONS :

These questions consist of two statements each, printed as *Assertion* and *Reason*. While answering these questions you are required to choose any one of the following four responses :

A. If both *Assertion* and *Reason* are true and the *Reason* is a correct explanation of the *Assertion*.

B. If both *Assertion* and *Reason* are true but *Reason* is not a correct explanation of the *Assertion*.

C. If *Assertion* is true but the *Reason* is false.

D. If both *Assertion* and *Reason* are false.

1. **Assertion.** Leaves are pinnatifid in Poppy.
   Reason. Here incisions are less than half way from margin to mid rib.
   A **B** **C** **D**
2. **Assertion.** In reticulate venation, veinlets are repeatedly branched and form a complex network.
   Reason. In parallel venation, the veins lie parallel to each other.
   A **B** **C** **D**
3. **Assertion.** In wheat, fruit is of caryopsis type.
   Reason. Pericarp is fused with testa.
   A **B** **C** **D**
4. **Assertion.** In basal placentation many ovules are present.
   Reason. It is bilocular.
   A **B** **C** **D**
5. **Assertion.** Castor seed is dicot endospermic seed.
   Reason. Seed is with two cotyledons and unconsumed endosperm.
   A **B** **C** **D**

6. **Assertion.** Flower is complete in *Petunia*.
   Reason. Perianth, androecium and gynoecium is present.
   A **B** **C** **D**
7. **Assertion.** Capitulum is also called racemose head.
   Reason. In umbel peduncle is reduced to a point.
   A **B** **C** **D**
8. **Assertion.** Fruit is cypsela in Compositae.
   Reason. Fruit is siliqua in Cruciferae.
   A **B** **C** **D**
9. **Assertion.** Stamens are 6, polyandrous and tetradynamous in *Brassica*.
   Reason. Stamens are arranged in two whorls with lateral two in outer whorl, and four in inner whorl with antero-posterior median pairs showing tetradynamous condition. Stamens are free.
   A **B** **C** **D**
10. **Assertion.** Stamens are syngenesious in Compositae.
    Reason. Filaments are fused and anthers are free in one group.
    A **B** **C** **D**
11. **Assertion.** Flowers are trimerous in family Solanaceae.
    Reason. Stamens are three in number and carpels are six in number.
    A **B** **C** **D**
12. **Assertion.** In family Liliaceae, perianth, stamens and carpels are present. But still it is incomplete.
    Reason. In complete flower calyx, corolla, androecium and gynoecium are present.
    A **B** **C** **D**
13. **Assertion.** Bract is represented by a scale, single veined called **lemma** in family Gramineae.
    Reason. Bracteole in family Gramineae is represented by two nerved **pale.**
    A **B** **C** **D**
14. **Assertion.** In cymose tap root system, oldest branch lies very near the growing point of the root while the youngest branch is farthest away from it.
    Reason. In cymose tap root system, the primary root itself stops growing after some time; but secondary roots carry on further growth of the root system.
    A **B** **C** **D** (*AIIMS 2007*)

ANSWERS

1. A;	**2.** C;	**3.** A;	**4.** D;	**5.** A;	**6.** C;	**7.** B;	**8.** B;	**9.** A;	**10.** C;
11. D;	**12.** A;	**13.** B;	**14.** A.						

E. REASONING TYPE QUESTIONS :

Give reasons for the following statements :

1. Stamens are tetradynamous in family Cruciferae.
2. Placentation is basal in Compositae.
3. In pea placentation is marginal.
4. Corolla is cruciform in Cruciferae.
5. Flower is actinomorphic in *Petunia*.
6. Odd sepal is anterior in Papilionaceae.
7. Anthers are fused and stamens are free in family Compositae.
8. The rhizome of ginger is found underground. But it is not root.
9. In *Opuntia*, stem is flat, leaf like and photosynthetic
10. Grain is a fruit not seed.
11. Sunflower is a heterogamous type of capitulum.
12. Leaf of *Coriandrum* is of decompound type.

ANSWERS

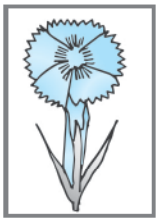
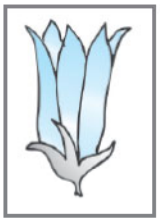
1. Total stamens are six. Arranged in two whorls of 2 + 4 each.
2. It is bicarpellary ovary, unilocular, uniovuled with ovule attached at the base.
3. In pea which belongs to family Papilionaceae, ovary is one chambered and ovules are borne on the placenta developing along the ventral suture.
4. Here, four unguiculate type of petals are arranged in a cross shaped fashion.
5. In *Petunia*, flower can be cut into two equal halves in more than plane, vertically.
6. Odd sepal always lie away from mother axis.
7. Due to syngenesious type of stamens.
8. It bears nodes, internodes and scale leaves.
9. Being succulent xerophyte, leaves in *Opuntia* are converted into spines and stem becomes flat, green and photosynthetic.
10. In this case pericarp is fused with testa.
11. It bears disc florets and ray florets.
12. In decompound type pinnate compound leaf is divided many times.

F. ADDITIONAL MULTIPLE CHOICE QUESTIONS :

Choose the correct answer :

1. Bicarpellary, syncarpous ovary with axile placentation is seen in :
   (a) Solanaceae (b) Caesalpinaceae (c) Asteraceae (d) Malvaceae
2. Which of the following is a merit in the Bentham and Hooker's system of classification?
   (a) The position of Gymnospermae in between dicots and monocots
   (b) Closely related families are placed apart
   (c) The placement of family Asteraceae in the beginning of Gamopetalae
   (d) The placement of order Ranales in the beginning
   (e) The placement of Orchidaceae in Microspermae
3. Match the following with correct combination :

	Column I		Column II
A	*Cuscuta*	1.	Saprophyte
B	*Eichornia*	2.	Pneumatophore
C	*Monotropa*	3.	Insectivorous plant
D	*Rhizophora*	4.	Parasite
E	*Utricularia*	5.	Root pocket

   (a) A-4, B-3, C-1, D-5, E-2 (b) A-4, B-5, C-1, D-2, E-3 (c) A-2, B-3, C-1, D-5, E-4
   (d) A-3, B-1, C-5, D-4, E-2 (e) A-2, B-5, C-4, D-3, E-1
4. (A)  (B) (C) (D) (E) 

   Code : The correct sequence of types of corolla in the figure given above is :
   (a) A – caryophyllaceous, B – papilionaceous, C – bilabiate, D – tubular, E – bell-shaped
   (b) A – papilionaceous, B – bilabiate, C – tubular, D – bell-shaped, E – caryophyllaceous
   (c) A – bilabiate, B – papilionaceous, C – caryophyllaceous, D – bell-shaped, E – tubular
   (d) A – caryophyllaceous, B – bilabiate, C – papilionaceous, D – tubular, E – bell-shaped
   (e) A – tubular, B – bell-shaped, C – caryophyllaceous, D – bilabiate, E – papilionaceous
5. Which of the following statements is/are true?
   (A) If the stem is jointed with solid nodes and hollow internodes, it is called caudex
   (B) In *Tridax* the stem is decumbent
   (C) Corm is a condensed form of rhizome growing more or less in vertical direction

(D) Sucker is an underground modification of stem
(E) Biparous type of cymose branching is seen in *Saraca*
Code :
(a) A, D and E only (b) B and C only (c) B, C and E only
(d) C and D only (e) D and E only

6. In the monocotyledonous seeds the endosperm is separated from the embryo by a distinct layer known as :
(a) Testa (b) Aleurone layer (c) Tegmen
(d) Scutellum (e) Coleptile

7. Match List I with List II and select the correct option :

	Column I		Column II
A	Spike	1.	*Bougainvillea*
B	Capitulum	2.	*Coleus*
C	Dichasial cyme	3.	*Adhatoda*
D	Multiparous cyme	4.	*Zinnia*
E	Verticillaster	5.	*Asclepias*

(a) A-3, B-4, C-1, D-5, E-2 (b) A-3, B-1, C-4, D-5, E-2 (c) A-2, B-4, C-1, D-5, E-3
(d) A-4, B-2, C-5, D-1, E-3 (e) A-5, B-4, C-1, D-3, E-2

8. Which of the following represents the floral characters of Liliaceae :
(a) Six tepals, zygomorphic, six stamens, bilocular ovary, axile placentation
(b) Tetramerous, actinomorphic, polyphyllous, unilocular ovary, axile placenation
(c) Trimerous, actinomorphic, polyandrous, superior ovary, axile placenation
(d) Bisexual, zygomorphic, gamophyllous, inferior ovary, marginal placentation
(e) Unisexual, actinomorphic, trilocular, inferior ovary, axile placentation

9. The botanical name of soyabean is :
(a) *Cajanus cajan* (b) *Glycine max* (c) *Glycyrrhiza glabra*
(d) *Abrus precatorius* (e) *Dolichos lablab*

10. Which of the following is / are not characteristic features of Asteraceae :
(A) Cypsela type of fruit (B) Syngenesious stamens (C) Ovary bicarpellary and superior
(D) Placentation marginal (E) Head type of inflorescence
(a) B, C and D only (b) C and E only (c) C and D only
(d) A and B only (e) C only

11. Family Podostemaceae is placed under the series :
(a) Multiovulatae aquaticae (b) Microembryeae (c) Daphnales
(d) Unisexuales (e) Heteromerae

12. Match the items in Column I with Column II and choose the correct answer :

	Column I		Column II
A	*Artemisia* sp	1.	Insecticide
B	*Solidago* sp	2.	Santonin
C	*Eclipta alba*	3.	Dropsy
D	*Chrysanthemum roseum*	4.	Tonic in spleen enlargement

(a) A-2, B-3, C-4, D-1 (b) A-1, B-2, C-3, D-4 (c) A-3, B-4, C-2, D-1
(d) A-4, B-3, C-2, D-1 (e) A-3, B-1, C-4, D-2

13. Replum is present in the ovary of flower of :
(a) Sunflower (b) Pea (c) Lemon (d) Mustard

14. Thorn of *Bougainvillea* and tendril of *Cucurbita* are examples of :
(a) Vestigial organs (b) Retrogressive evolution (c) Analogous organs (d) Homologous organs

15. Dry indehiscent single-seeded fruit formed from bicarpellary syncarpous inferior ovary is :
(a) Berry (b) Cremocarp (c) Caryopsis (d) Cypsella

16. The fleshy receptacle of syconous of fig encloses a number of :
(a) Berries (b) Mericarps (c) Achenes (d) Samaras

17. Pneumatophores are present in :
(a) Xerophytes (b) Hygrophytes (c) Mesophytes (d) Halophytes

18. Trimerous flowers, superior ovary and axile placentation is characteristic of :
(a) Liliaceae (b) Cucurbitaceae (c) Solanaceae (d) Compositae

19. What differentiates leaf of dicots from monocots?
(a) Parallel venation (b) Differentiation of palisade and spongy parenchyma
(c) Stomata only on upper side (d) Stomata both on upper and lower sides

20. Botanical name of gram is :
(a) *Cicer arietinum* (b) *Phaseolus aureus* (c) *Lablab purpureus* (d) *Dolichos*

21. Primary root is :
1. Positively geotropic 2. Positively hydrotropic 3. Negatively geotropic 4. Negatively hydrotropic
Code :
(a) 1, 2 and 3 are correct (b) 1 and 2 are correct (c) 2 and 4 are correct (d) 1 and 3 are correct

22. Hairy styles help in the dispersal of fruits in :
1. *Clematis* 2. *Aristolochia* 3. *Naravelia* 4. Mango
Code :
(a) 1, 2 and 3 are correct (b) 1 and 2 are correct (c) 2 and 4 are correct (d) 1 and 3 are correct

23. The seeds which have separate endosperm :
1. Maize 2. Onion 3. Rice 4. Bean
Code :
(a) 1, 2 and 3 are correct (b) 1 and 2 are correct (c) 2 and 4 are correct (d) 1 and 3 are correct

24. Ginger is an underground stem. It is distinguished from root because :
(a) It lacks chlorophyll (b) It stores food
(c) It has nodes and internodes (d) It has xylem and vessels

25. What type of placentation is seen in sweet pea?
(a) Basal (b) Axile (c) Free central (d) Marginal

26. Simple cluster of radial leaves with exstipulate and parallel venation and cyme or umbel inflorescence are the characteristics of :
(a) Poaceae (b) Liliaceae (c) Asteraceae (d) Fabaceae

27. Tobacco and *Petunia* belong to the family :
(a) Poaceae (b) Fabaceae (c) Solanaceae (d) Brassicaceae

28. The order of opening of floral parts from the periphery towards the centre is called :
(a) Acropetal (b) Centripetal (c) Centrifugal (d) Basipetal

29. The bladder helps in floating and trapping insects is found :
(a) *Zizyphus* (b) *Utricularia* (c) *Nepenthes* (d) *Acacia*

30. Which one of the following inhibits seed germination for a particular period?
(a) Light (b) Water (c) Carbon dioxide (d) Dormancy

ANSWERS

1. (a);	**2.** (d);	**3.** (b);	**4.** (a);	**5.** (b);	**6.** (b);	**7.** (a);	**8.** (c);	**9.** (b);	**10.** (c);
11. (a);	**12.** (a);	**13.** (d);	**14.** (d);	**15.** (d);	**16.** (c);	**17.** (d);	**18.** (a);	**19.** (b);	**20.** (a);
21. (b);	**22.** (d);	**23.** (a);	**24.** (c);	**25.** (d);	**26.** (b);	**27.** (c);	**28.** (b);	**29.** (b);	**30.** (d).

Chapter Practice Test

Time Allowed : 1:30 Hours *Maximum Marks : 35*

1. What are sucking roots ? (1)
2. What is sympodial axis ? (1)
3. Name the various types of leaves . (1)
4. What is spikelet type of inflorescence ? (1)
5. Define nut. Give one example. (1)
6. What is opposite and decussate type of phyllotaxy? (2)
7. What is replum? (2)
8. What is palmate leaf? (2)
9. Describe the umbel type of inflorescence. (2)
10. What are phylloclades? (2)
11. Draw the floral diagram of *Allium cepa*. (3)
12. Write the economic importance of family Solanaceae. (3)
13. Discuss the structure of maize grain. (3)
14. Differentiate between spadix and capitulum. (3)
15. Discuss the statement 'Flower is a modified shoot'. (3)
16. Describe the different regions of a root and draw a well labelled diagram. (5)

❑❑❑

To check your performance, see ANSWERS TO CHAPTER PRACTICE TEST at the end of Part I of the book.

CHAPTER 6

ANATOMY OF FLOWERING PLANTS

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CHAPTER PRACTICE TEST 49

TISSUES

Cells of plants exhibit great variation in size and structure. **A group of cells performing essentially the same function and commonly of similar structure is called a tissue.**

Every organ of plant as stem, root and leaf is made of tissue. Usually in an organ various types of tissues are present. They perform together interrelated functions.

TYPES OF PLANT TISSUES

Plant tissues are mainly classified on the basis of characters like nature of cells, origin and methods of development, position in plant body etc. Tissues are of two types on the basis of stages of development :

(a) Meristematic tissue (b) Permanent tissue

(A) MERISTEMATIC TISSUE

The group of young cells that have the capacity of active cell division is called meristem. The meristematic tissue shows the following characters :

(i) They are living and thin walled.
(ii) The vacuoles are few and small in size.
(iii) The cells contain a dense protoplasm and conspicuous nuclei.
(iv) The cells may be spherical, oval or polygonal in shape.
(v) They are compactly arranged and without intercellular spaces.
(vi) The cells are immature and undifferentiated and are capable of dividing indefinitely. The plane of division may be anticlinal, periclinal or irregular.
(vii) The plastids are in proplastid stage. Secondary meristems may, however, bear plastids.
(viii) Meristematic cells do not store reserve food material and are in active stage of metabolism. Inorganic crystals and other ergastic substances are absent in meristematic cells.

They are mostly found at the apices of root and shoot.

Classification or types of meristems

Meristems are classified on the basis of their origin on plane of cell division, position in plant body and function.

(i) Meristematic tissue based on origin

(a) Primary meristem
(b) Secondary meristem

(a) Primary meristem. These are derived directly from the meristems of embryo (**promeristems** *i.e.* tip of radicle and plumules). They persist throughout the life.

Table 1. Differences between Primary meristem and Secondary meristem.

Characters	Primary meristem	Secondary meristem
1. Origin	From promeristem or embryonic meristem.	Appears as new meristem from permanent tissue.
2. Central vacuole	Cells are without central vacuole.	Usually with central vacuole.
3. Result	Gives rise to primary permanent tissue of primary body (exception–intrafascicular cambium)	Gives rise to secondary or supplementary tissues.
4. Examples	Protoderm, procambium and ground meristem.	Vascular cambium except intrafascicular cambium, root cambium and cork cambium.

They show their presence at the apices of root and stem and primordia of leaves. They thus represent the **apical meristems**, **intercalary meristems** and **intrafascicular cambium** in open dicot vascular bundles. The growth which appears due to the activity of apical and intercalary meristems is called **primary growth** while growth taking place due to activity of intrafascicular cambium is called **secondary growth.**

(b) Secondary meristem. They are formed as **new meristem in permanent cells by rejuvenation or re-differentiation.** They are usually lateral in position and are responsible for increasing the diameter of plant organ. Secondary meristems appear in the form of cork cambium (appears from mature cells of epidermis, cortex or pericycle), interfascicular cambium (from cells of ground tissue, medullary ray cells), entire cambium of root (from conjunctive parenchyma).

The cambium brings about increase in girth or diameter of the organ.

(ii) Meristematic tissue based on plane of cell division :

Following three types can be recognised on the basis of plane of cell division :

(a) Mass meristem

(b) Plate meristem

(c) Rib meristem

(a) Mass meristem. Here cells divide in all the planes thus resulting increase in volume. It can be noticed in the meristem of cortex, pith etc.

(b) Plate meristem. The cells divide in two planes. They form flat surfaces by increasing area of organ *e.g.* Leaf formation.

(c) Rib meristem. The cells divide only in one plane *e.g.*, formation of filaments in algae.

(iii) Meristematic tissue based on position (Fig. 1).

Based on position meristems can be classified into following types :

(A) Apical meristem.

(B) Intercalary meristem.

(C) Lateral meristem.

(A) Apical meristem. They are present at the apices of stem, root and branches. These are responsible for increasing the length. Many cells form the apical meristems. **However, in pteridophytes, one cell constitutes the meristem.** It includes both promeristem and primary meristem.

Function. (i) Due to activity of apical meristem, the organ increases in length and differentiate into primary tissues.

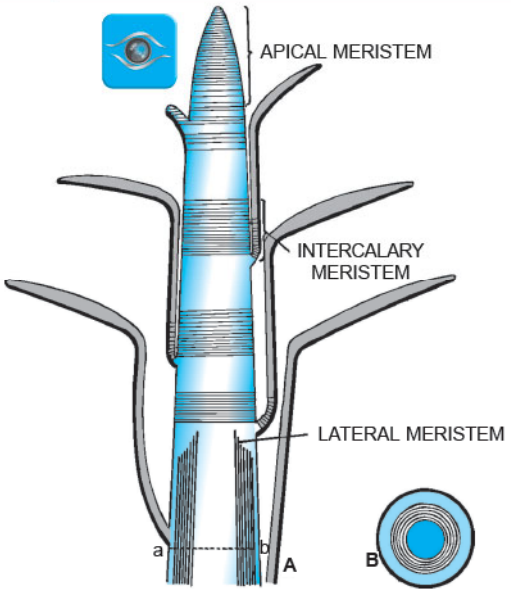


Fig. 1. Location of different types of meristems in a plant.
A. L.S. shoot showing different position of meristems;
B. T.S. shoot at the point of dotted arrow.

(ii) It is responsible for primary growth of plant body.

(a) Shoot apex

According to **tunica-corpus** theory of **Schmidt** (1924), leaf primordia protect the dome shaped shoot apex which can be differentiated into (i) **Tunica**—an outer zone which gives rise to epidermis or protoderm (Fig. 2). Cell division occurs at right angle to the surface of apex (anticlinal) finally giving rise to surface growth. (ii) **Corpus**—lower multilayered zone which finally gives rise to procambium and ground meristem. Procambium forms vascular tissue and ground meristem gives rise to ground tissue.

According to **histogen** theory of **Hanstein** (1870), the shoot apex is differentiated into three histogens or regions (Fig. 4A) : **(a) dermatogen** (forms epidermis), **(b) periblem** (forms cortex and endodermis) and **(c) plerome** (forms pericycle, vascular bundles, medullary rays and pith).

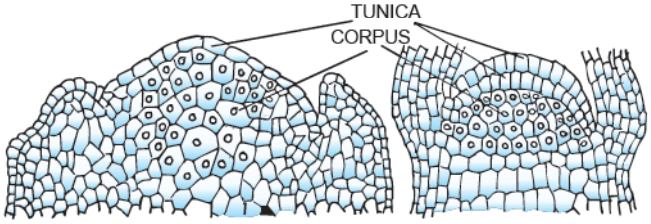


Fig. 2. L.S. of shoot apex to show tunica and corpus.

(b) Root apex

It is covered by root cap. It can further be differentiated into five regions :

(i) Protoderm. Forms epidermis or epiblema and root cap in dicots.

(ii) Calyptrogen. Found in monocots and is responsible for the formation of root cap.

(iii) Procambium. Gives rise to vascular strands.

(iv) Ground meristem. Takes part in the formation of pith, cortex, endodermis and pericycle.

(v) Quiescent centre. In this region the cells divide at a very slow rate (Fig. 3). It occupies the central part of root apex. It shows low mitochondrial activity. Clowes, a British plant anatomist noticed this slow activity of cell division in a few cells of central part of distal region of root apex. This low rate of mitosis is due to less protein synthesis and low level of DNA which are mainly needed for cells to undergo cell division.

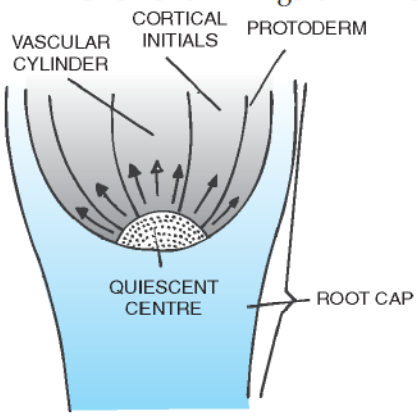


Fig. 3. L.S. Root tip.

Hanstein in histogen theory gave the idea that as in shoot apex, root apex has also three histogens:

(a) dermatogen (forms epiblema and root cap in dicots),

(b) periblem (forms cortex and endodermis), and

(c) plerome (forms pericycle, vascular strand and pith, if any),

(B) Intercalary meristems. These are the parts of apical meristems, which get separated from apex due to the development of permanent tissue in between. Intercalary meristems are found at the base of leaves above the nodes *e.g.* grasses, *Equisetum*, or below the nodes *e.g.* Mint.

Function. It increases the length of internodes and is finally consumed.

(C) Lateral meristem. It is formed laterally from the procambial strands *i.e.* cambium present between xylem and phloem and the cork cambium of roots and stems. The cells divide only in periclinal plane and thus they add to girth. This type of meristem shows its activity after sometime in plant organ.

Function. Lateral meristem undergoes secondary growth and increases the diameter of an organ.

(iv) Meristematic tissue based on function:

The first formed meristem **(Promeristem)** gets differentiated into the following three regions:

(i) Protoderm (gives rise to epidermis).

(ii) Procambium (gives rise to phloem, xylem and cambium).

(iii) Ground meristem (forms cortex, pericycle, medullary rays and pith).

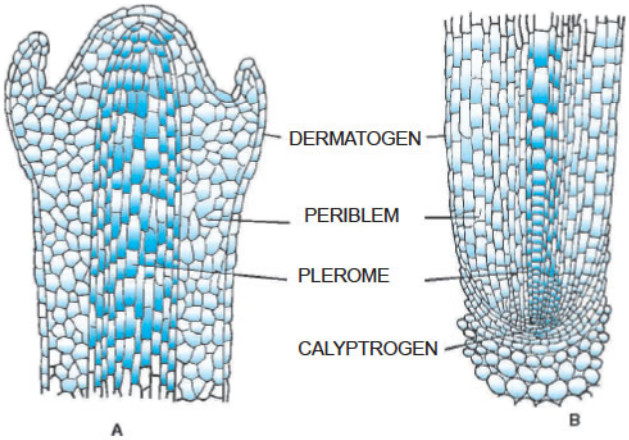


Fig. 4. A. L.S. stem apex to show meristems;
B. L.S. root apex to show meristems.

Table 2. Promeristems and the Tissue Systems.

Meristem	Permanent region	Tissue system
Dermatogen	Epidermis	Epidermal tissue system
Periblem	Cortex	Hypodermis; General cortex; Endodermis → Ground tissue system
Plerome	Stele	1. Pericycle 2. Pith rays 3. Pith Vascular bundle 1. Phloem 2. Cambium 3. Xylem → Vascular tissue system

Table 3. Differences between Apical meristem and Lateral meristem.

Characters	Apical meristem	Lateral meristem
1. Location	Present at the apices of main and lateral shoots and roots.	Present on the sides of plant organs.
2. Nature	Usually primary meristem.	May be primary or secondary in origin.
3. Growth	Increases length.	Increases girth.
4. Examples	Shoot apex and root apex.	Vascular cambium, cork cambium and marginal meristem of some leaves.

(B) PERMANENT TISSUE

Permanent tissues are those in which growth has ceased, at least temporarily. Permanent tissues as a whole in part may again become meristematic. Permanent tissues are composed of cells which have lost the power of division, having attained their definite form, size and shape. They may be **primary** or **secondary**. The primary permanent tissues appear from apical meristems of stem and root. On the other hand, secondary permanent tissues are derived from lateral meristematic tissues *e.g.* cambium. Permanent tissues may be thin walled or thick walled, living or dead. Mainly on the basis of constituent cells, permanent tissues are classified into two groups *i.e.* **simple** and **complex**. Simple tissues are made up of homogeneous or similar type of cells. On the other hand complex permanent tissues are composed of different types of cells viz. heterogeneous. This is true of tissues like xylem and phloem.

(I) SIMPLE PERMANENT TISSUES

(a) Parenchyma. Parenchyma is most commonly found in plants. It consists of mainly thin walled cells, which are usually isodiametric *i.e.* not much longer than broad. Typical parenchymatous cells are oval, spherical or polygonal in shape. The cells are living and thin walled which are made up of cellulose. Xylem parenchyma is thick walled. They retain their capacity to divide at maturity. They are many sided frequently with 12-14 faces. The parenchyma cells at growing tips of root and stem constitute **meristematic** tissue. It is called the fundamental tissue of the plant because it really constitutes the ground substance where other tissues remainembedded. Parenchyma is precursor of other tissues. As the parenchyma cells contain living protoplasm, they perform the important function like storage of food, photosynthesis, secretion, excretion etc. (depending on the type of parenchyma). When parenchyma tissue contains chloroplasts, it is called **chlorenchyma** *e.g.* leaves etc. and is responsible for photosynthesis. Fairly large air cavities may be present in the parenchyma cells of aquatic plants (hydrophytes), which provide buoyancy to the plants in addition to normal aeration and such tissue is called **aerenchyma** (Fig. 5D). **E. B. Matzke** (1940) is of the view that 14 faces of an ideal parenchymatous cell are due to **Orthic tetra kai decahedron** (a polyhedron of 8 hexagonal and 6 quadrilateral cells). In some cases parenchymatous cells become long and taper at either end *e.g.* in pericycle of some plants. Such parenchymatous tissue is called **prosenchyma** (Fig. 5E).

The parenchymatous cells are also found in xylem and phloem which help in the conduction of water and food materials and are known as **xylem parenchyma** and **phloem parenchyma** respectively.

Idioblasts are specialized parenchymatous cells which produce and store tannins, oils and calcium oxalate crystals.

Functions

1. It stores food in the form of starch, proteins, oils and fats.

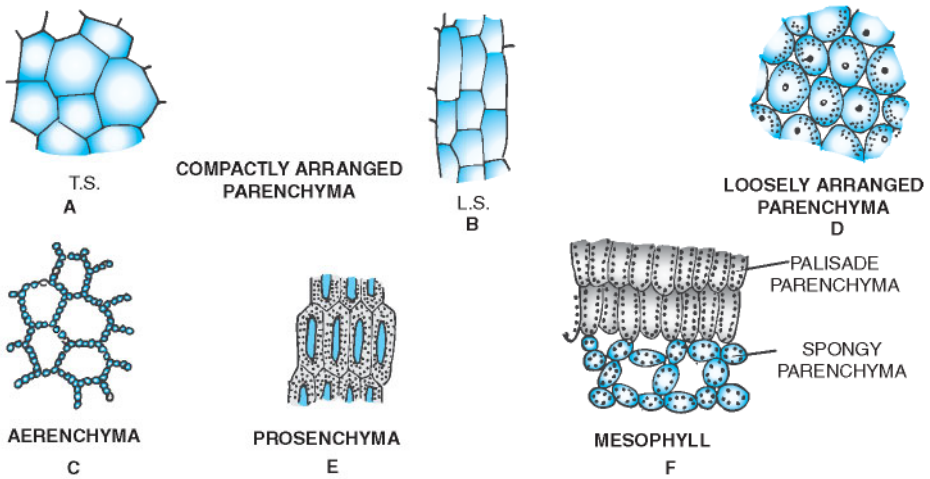


Fig. 5. Various kinds of parenchyma.

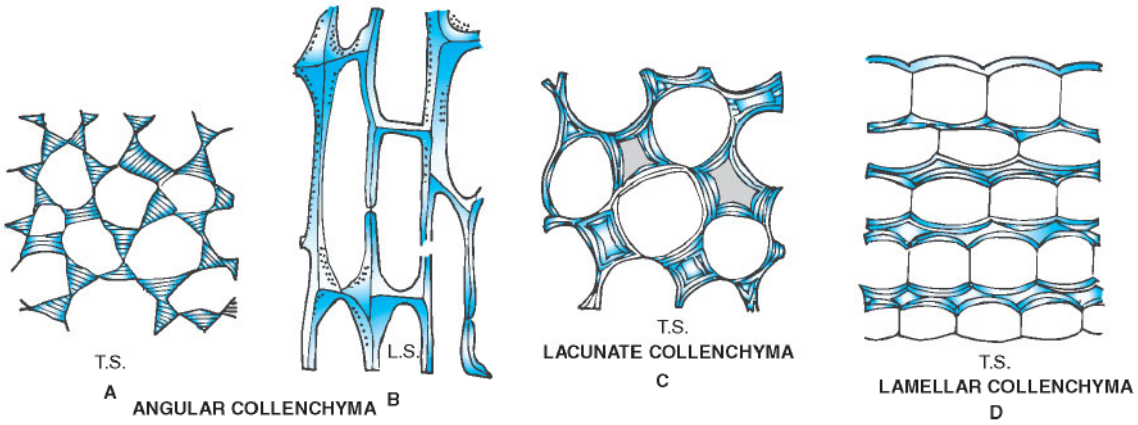


Fig. 6. Collenchyma.

2. In plants like *Opuntia*, *Aloe* etc. parenchymatous cells store water to become succulent.

3. In hydrophytes, they have large air spaces to keep up buoyancy of plant. These air spaces also help in gaseous exchange.

4. By keeping the cells turgid, parenchyma provides rigidity to the plant.

5. Chlorophyll containing parenchyma (chlorenchyma) helps in photosynthesis.

6. Oil, nectar etc. are secreted by secretory organs which are made up of parenchymatous cells.

7. They help in slow conduction of water and food materials.

8. Parenchyma protects the internal tissues from environment by developing epidermis.

(b) Collenchyma. This type of tissue possesses localised thickenings on the cell walls and is found only in primary body. It is lacking in secondary body of dicots. So, the collenchyma is made up of somewhat elongated cells with cellulose thickenings found as longitudinal strips, usually confined to corners of cells. They are alive and have protoplasm. It is mainly a temporary supporting tissue and usually occurs beneath the epidermis in the outer parts of herbaceous stem and in the petioles and mid-ribs of leaves. Collenchyma cells appear polygonal in crosssection. On the basis of thickening of cell wall and arrangement of cells collenchyma can be :

(i) Angular collenchyma. In such cases thickening is confined to junctions between the cells and found most commonly (Fig. 6A, B).

(ii) Lacunate collenchyma. In such cases deposition is restricted to corners but they bear intercellular spaces or lacunae (Fig. 6C).

(iii) Lamellar collenchyma. Here the collenchyma is constituted by vigorously thickened tangential walls. Cells are compactly arranged. Cells look like bands or plates (Fig. 6D).

Functions

1. It provides rigidity and strength to the plant body due to thickenings.

2. Chloroplast containing collenchyma is responsible for photosynthesis.

3. It resists the tearing effect of the wind on the leaves due to its presence along the margins of some leaves.

4. It provides mechanical support to leaves as it may be present on both the sides of vascular bundles or as isolated patches.

(c) Sclerenchyma. It is also a simple, permanent type of tissue. Two types of cells—**fibres** and **sclereids** are included in sclerenchyma. They all are mainly responsible for providing strength and mechanical support. Both fibres and sclereids have greatly thickened walls due to deposition of lignin and cellulose, which are secreted by protoplast of these cells. After gaining maximum thickness on their walls, protoplast die. Thus they are dead at maturity.

(i) Sclerenchyma fibres. These are much elongated with tapering ends (Fig. 7). They have great strength and flexibility. They are also found with xylem and phloem tissues. The length of fibres usually range from 1-2 mm but in flax it is 9.70 cm. Fibres attain their enormous length by symplastic and intrusive growth.

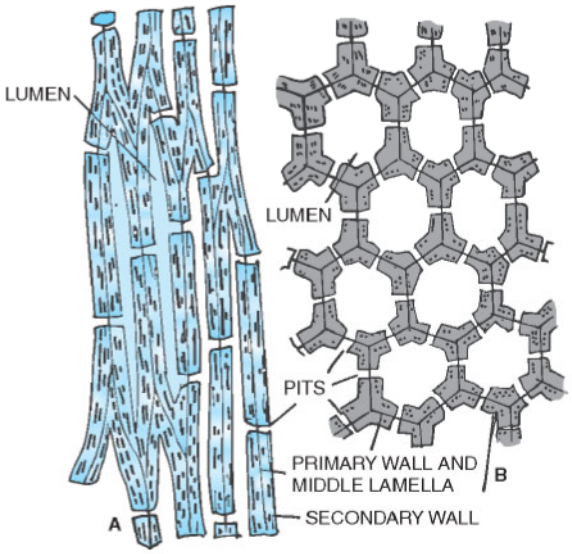


Fig. 7. Fibres **A.** L.S.; **B.** T.S.

Secondary wall material is laid down progressively from the older part of the cell toward the tips and is completed after the tips stop intrusive growth. They are widely found in plants as chief mechanical tissue. They are distributed in separate strands or cylinders in cortex. They also occur with vascular bundles as sheaths or bundle caps. They are associated with xylem and phloem as xylem fibres and phloem fibres.

(ii) Sclereids form the major part of walnut shells and those of other kinds of nuts. They constitute gritty masses in the skin and pulp of pears. They also form an important part of the bark of trees. Some of the sclereids may function as stone cells (Fig. 8A). The stone cells are irregularly shaped but not much longer than width. They are mainly found in fruits and seeds. The shells of nuts contain stone cells. They are found in pulp of guava, pear and sapota fruits. The stone cells are mainly responsible for grittiness in the pulp of these fruits.

Few other types of sclereids are :

(i) Macro–sclereids. Columnar-shape or rod-like *e.g.* epidermal covering of **legume seeds** (Fig. 8C).

(ii) Osteo–sclereids. Bone-like in shape or rod-like with swollen ends *e.g.* sub-epidermal covering of **legume** seeds (Fig. 8D).

(iii) Astro–sclereids. They are irregularly branched or star shaped cells *e.g.* petiole of **lotus** and **tea** leaves (Fig. 8B).

(iv) Filiform–sclereids. They are fibre-like, sparingly branched *e.g. Olea* (Fig. 8E).

Functions

1. Fibres are mainly responsible for providing the plant, mechanical strength. Thus they help in retaining their position.

2. Sclerenchyma saves the plant from various stresses and strains of environmental forces like strong wind etc.

3. Sclerenchyma in leaves provides rigidity and saves it from collapsing.

4. Sclereids provide grittiness in the pulp of many fruits.

(II) COMPLEX PERMANENT TISSUES

Vascular tissue (xylem and phloem). The conducting region of a plant is made up of xylem and phloem. They constitute complex permanent tissues because in them many kinds of cells occur. In contrast, simple tissues discussed earlier are made up of single type of cells. Both xylem and phloem mainly function as conducting tissues. Xylem is responsible for the conduction of water and dissolved mineral salts and phloem mainly carries food. Both xylem and phloem are an assemblage of living and dead cells and may be primary or secondary in origin.

(A) XYLEM

Xylem is made up of four kinds of cells. *i.e.*

(i) Tracheids (ii) Tracheae or vessels (iii) Xylem fibres (iv) Xylem parenchyma.

(i) Tracheids. In pteridophytes and gymnosperms tracheids work as main element of conduction. A tracheid is an elongated cell with tapering ends. They develop from procambial cells by lignification on their cells in primary xylem. The tracheids are about 1 mm in length and made up of single cell. The tracheids are devoid of protoplasm and hence dead. The walls constituting the tracheids are hard, thick and lignified. The secondary walls are deposited in the form of thickenings of lignin on inner surface of original cell wall.

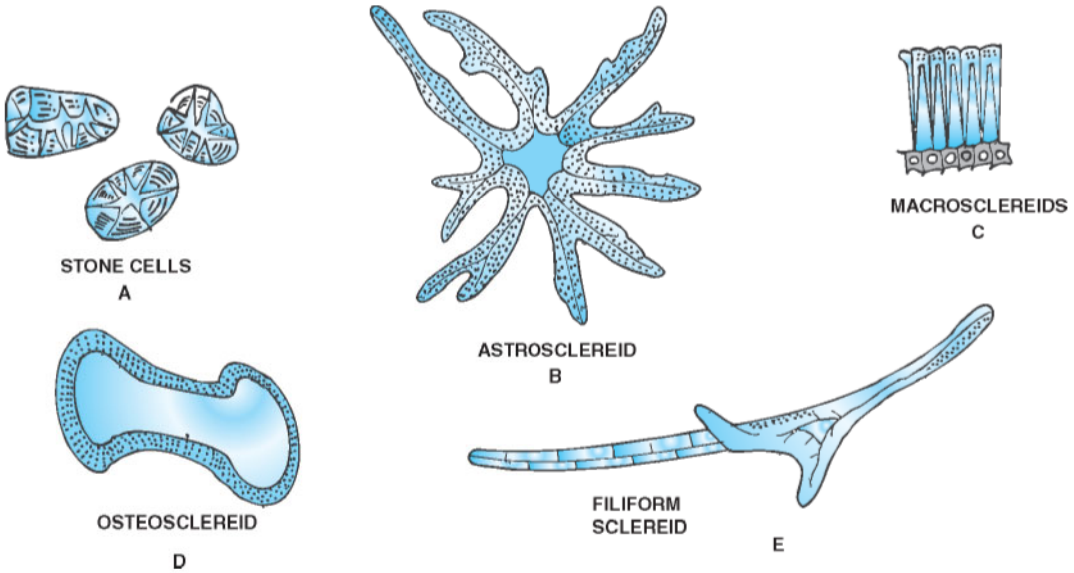


Fig. 8. Various types of sclereids.

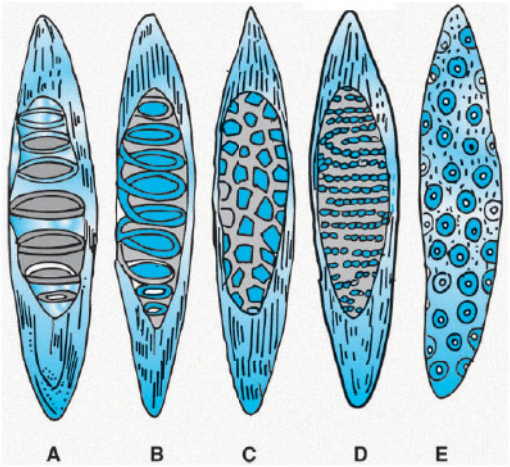


Fig. 9. Types of thickenings found in tracheids. **A.** Annular; **B.** Spiral; **C.** Reticulate; **D.** Scalariform; **E.** Pitted.

Tracheids are of following types depending upon the secondary thickenings :

(a) Annular. Lignin (thickening material) is deposited in the forms of rings (Fig. 9A).

(b) Spiral. Thickening is laid down in the form of a spiral or helix (Fig. 9B).

(c) Reticulate. The lignin is deposited in the form of many spirals which intercross each other to form a network or reticulum (Fig. 9C).

(d) Scalariform. When the thickening occurs in the form of incomplete transverse bands and gives a ladder-like appearance (Fig. 9D).

(e) Pitted. In this type the whole of inner surface of wall is uniformly thickened except for small areas here and there, where it remains unthickened. These unthickened areas are called pits. The pits usually occur in pairs and are of two types (Fig. 9E) :

1. Simple pits. When the width of pit is uniform throughout.

2. Bordered pits. Such pits have flask-like cavity with narrow aperture and wide base (Fig. 10A).

The wall in between a bordered pit pair is called as pit **membrane** or **closing membrane**. The closing membrane has a central thickening called as **torus**. The unthickened portion of closing membrane around torus is called **margo**. If the bordered pit is paired by a single pit of a contiguous element, it is called as **half bordered pit** (Fig. 10 B). Bordered pits are better developed in gymnosperm. Sometimes the bordered pit may be provided with arc like thickenings of primary wall and middle lamella on either side, called as **crassulae** (Fig. 10C.) If these thickenings are rod like, they are called as **rims** or **bars of sanio.**

(ii) Tracheae or **Vessels.** Vessels are made up of row of cells, placed one above the other with their intervening walls (septa) absent due to dissolution. Vessels at maturity like tracheids lack protoplasm hence dead. The cell cavity or lumen is wide. Vessels like tracheids depending upon various types of thickenings are of various types as : Annular, spiral, scalariform, reticulate and pitted (Fig. 11).

Distribution of vessels. The vessels are found mainly in angiosperms However, they have been reported in

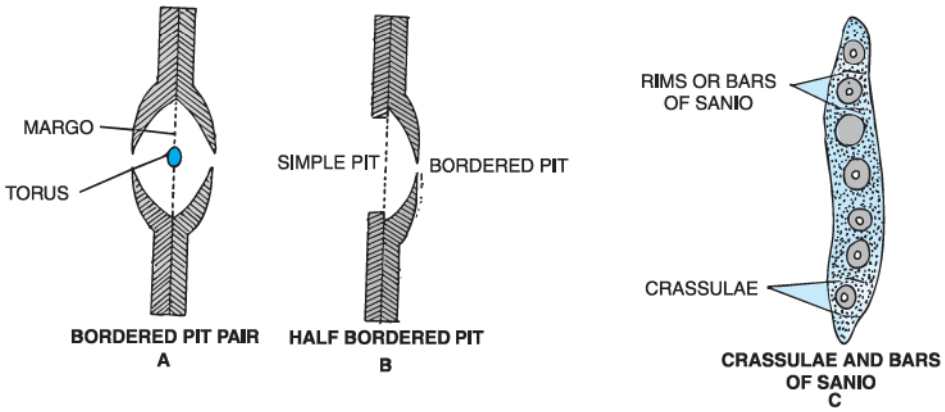


Fig. 10. A. Bordered pit pair; **B.** Half bordered pit; **C.** Crassulae and bars of sanio.

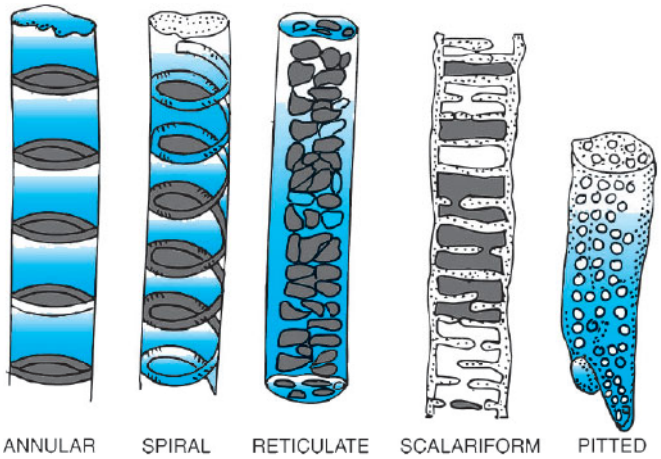


Fig. 11. Different kinds of vessels.

Selaginella, *Adiantum* (Pteridophytes), *Gnetum*, *Ephedra* (Gymnosperm).

On the basis of vessels, the woods have been classified as under :

(a) Non-porous wood. It lacks vessels *e.g.* gymnosperms.

(b) Porous wood. It bears vessels. In **ring porous wood** vessels are arranged in ring like fashion *e.g. Quercus*. In **diffuse porous wood,** vessels are uniformly scattered in secondary xylem *e.g. Populas* and *Salix*.

The major **differences** between tracheids and vessels are :

1. Tracheid is formed from a single cell which is imperforated. Vessel is made up of many cells with one or many perforations at each end.

2. Tracheids are comparatively narrower as compared to vessels.

3. Tracheids bear more thickened walls and narrow lumen as compared to vessels.

4. Tracheid is about 1 mm in size as compared to vessel which is several cms. in length.

(iii) Xylem fibres (Wood fibres). They are the sclerenchymatous cells associated with xylem tissue. They are more abundant in secondary xylem and provide more mechanical strength. They have extremely thick walls and bear narrow lumen. The walls are highly lignified. They are dead cells. Some tracheids resemble in structure with that of xylem fibres are called **fibre tracheids.**

(iv) Xylem parenchyma (Wood parenchyma). It consists of living parenchymatous cells associated with xylem. The walls are thin and made up of cellulose. The cells are living and serve the function of storage of food. It also helps in lateral conduction of water and minerals. Wood parenchyma cells are generally elongated in vertical direction in secondary xylem. In secondary xylem the cells become thickened and slightly lignified.

Perforation plate is the region where the vessels are connected with other through a pore. It is formed at the end walls and constitutes pipes like continuity of vessels lying one above the other. The perforation plate is called **simple** if the entire end wall dissolves and there is one opening. In plants like *Liriodendron* perforation plate is **multiple** because it bears many pores or openings. Multiple perforation plates are of three types :

1. Scalariform multiple perforation plate. Here the pores are transversely elongated and arranged in a ladder like fashion (Fig. 12B).

2. Reticulate multiple perforation plate. Here the polygonal pores are arranged in a net like pattern (Fig. 12C).

3. Ephedroid or foraminate multiple perforation plate. In this type, many circular perforations lie scattered in perforation plate (Fig. 12D).

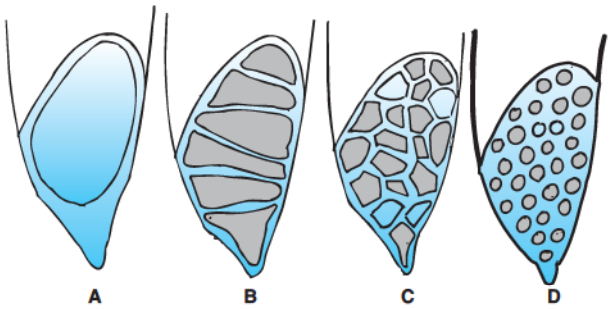


Fig. 12. Kinds of perforation plates,
A. Simple; **B.** Scalariform; **C.** Reticulate;
D. Ephedroid of foraminate.

Protoxylem and metaxylem

Depending upon the **time of origin** in relation to development and structural differences, the xylem is of two types *i.e.* **protoxylem** and **metaxylem.** The **protoxylem is the first formed xylem**, where lignification starts before the completion of elongation. Protoxylem is usually made up of tracheids, vessels and xylem parenchyma. Tracheids and vessels usually possess annular or spiral thickenings. The **late formed xylem is**

called as metaxylem. It bears larger tracheids and vessels and may be of reticulate, scalariform or pitted types. In such cases lignification takes place after completion of elongation.

Depending upon the **relative position** of protoxylem to metaxylem, xylem is of three types:

(i) Exarch. Here the protoxylem lies towards the outside of metaxylem *e.g.* roots.

(ii) Endarch. In this condition, protoxylem lies towards the centre of axis *e.g.* stems.

(iii) Mesarch. When protoxylem lies in the middle of metaxylem *e.g.* ferns.

Primary xylem and Secondary xylem

The xylem is said to be primary xylem when its elements are differentiated from procambium situated below the growing apices of the stem and roots. Secondary xylem represents the xylem developed from vascular cambium during the process of secondary growth.

Functions of Xylem. Xylem performs two main functions :

1. Conduction of water **2.** Mechanical strength

(B) PHLOEM

Phloem is also known as **bast** because phloem fibres of some plants *e.g.* jute, flax and hemp are used for binding purposes. They are used for making threads, ropes and coarse textiles. **Haberlandt** called phloem as **leptom**. It is a specialized complex tissue and is mainly responsible for translocation of food. It is formed of the following types of cells :

(i) Sieve tubes. They are elongated tube-like cells. Sieve tubes are placed end to end. They are thin walled and have larger lumens. Their transverse walls are oblique and are perforated to constitute **sieve plates** (Fig. 13 A, B). A sieve plate bears number of sieve pores in one or more well defined **sieve areas.** Sieve areas are also organised on the lateral wall of sieve tube elements but are less differentiated than those found on sieve plate. Sieve plate is further of two types :

(a) Simple sieve plate. It bears single sieve area.

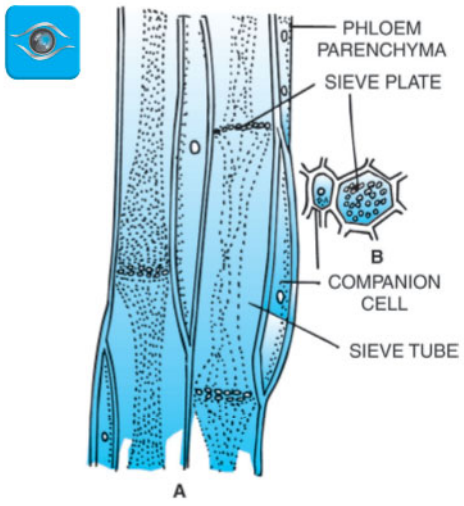


Fig. 13. A,B, Longitudinal and cross sections of phloem.

(b) Compound sieve plate. It bears more than one sieve areas (Fig. 15).

Sieve tubes are tubular channels formed from a row of cells in longitudinal series. A young tube cell bears protoplasm, nucleus and other organelles. Later on, nucleus is lost. The protoplasmic strands of one sieve tube extend through the pores of sieve plate to adjacent sieve tube. In winter, sieve plates are protected by a pad called callus formed by deposition of insoluble carbohydrate called **callose**. It gets dissolved in spring. Sieve tubes are responsible for conduction of food from leaves to other parts of plants.

(ii) Sieve cells. These are elongated and narrow cells. They bear sieve pores but sieve areas are not specialised and do not aggregate to form sieve plates. They are found in lower vascular plants. They have longer functioning period than sieve tube elements.

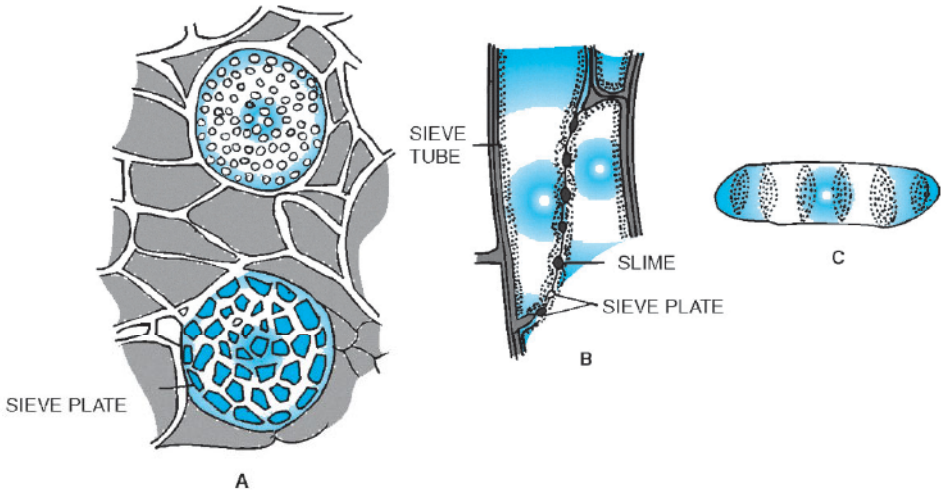


Fig. 14. A. Different types of perforations in sieve plates;
B. Several sieve plates on oblique end wall; **C.** End wall as surface view of **B.**

(iii) Companion cells. These are specialised thin walled parenchymatous cells found to be associated with sieve tubes (Fig. 13). They are thin walled and contain dense cytoplasm and prominent nuclei. They are found on sides of sieve tubes. Both sieve tube and companion cell appear from the same mother cell. Nuclei of companion cells control the metabolic activities of sieve tube. The companion cells are found in angiosperms only. In gymnosperms, no companion cells are found, but there are some special parenchyma cells associated to sieve cells called **albuminous cells.**

(iv) Phloem parenchyma. These are thin walled living parenchymatous cells. They are absent in most of monocots and herbaceous dicots. The cells contain cytoplasm and nucleus. They store food material and may show the presence of crystals, tannins, mucilage, latex etc.

(v) Phloem fibres. In primary phloem they are absent or are very few. However, they are abundantly present in secondary phloem. They are made up of thick walled sclerenchymatous cells and are mechanical in function. They are also called **bast fibres.**

Obliteration

After the loss of protoplast, a sieve element is crushed by the pressure of adjoining cells and its contents are absorbed by the adjoining cells. This crushing and absorbing process of sieve elements and companion cells is called **obliteration.**

Protophloem and metaphloem

Protophloem is the first formed phloem. The sieve elements constituting the phloem are narrow and inconspicuous. During the development of plant body protophloem usually gets crushed by the process of obliteration.

Metaphloem is the late formed phloem. It bears wider and larger sieve elements. The companion cells which are generally absent in protophloem are present or may represent the some modified form. In metaphloem of dicotyledons, the fibres are usually absent.

Primary phloem and secondary phloem. The phloem which is formed from the **procambial strands** of shoot and root apices represent the **primary phloem.**

The phloem formed due to the activity of **vascular cambium** during secondary growth is called **secondary phloem.**

Transfer cells. In short distance, phloem transport of metabolites is carried through specially formed **transfer cells.** These cells bear peculiar wall ingrowths.

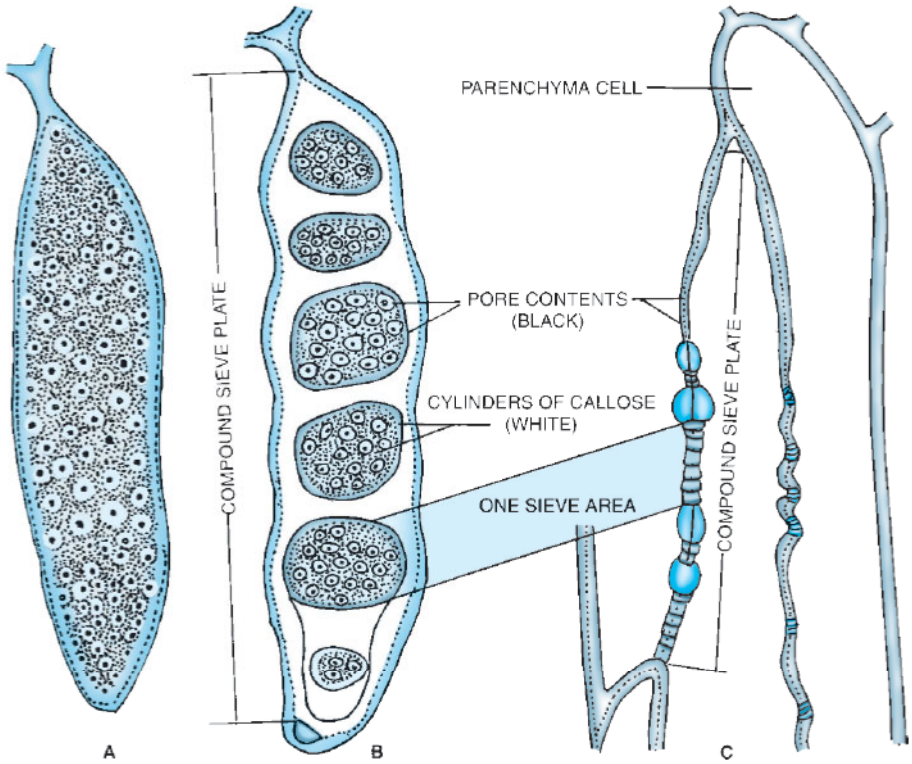


Fig. 15. Sieve plates : **A.** Simple sieve plate in surface view; **B** and **C.** Compound sieve plates; **B.** In surface view; **C.** In sectional view.

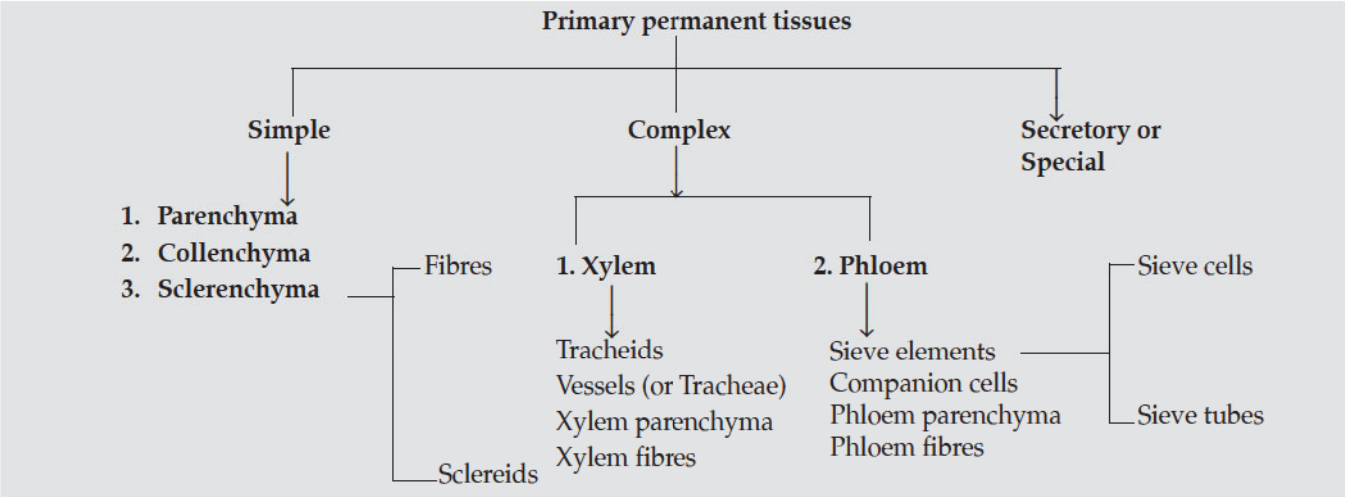


Table 4. Differences between Meristematic cells and Permanent cells.

Characters	Meristematic cells	Permanent cells
1. Central vacuole	These cells do not have large central vacuoles.	These cells often have large vacuoles.
2. Shape	They are thin walled and iso-diametric.	They may be thin or thick walled. They have permanent shape.
3. Division	These cells can divide and produce new cells.	These cells have lost the power of growth and division.

Table 5. Differences between Parenchyma and Collenchyma.

Characters	Parenchyma	Collenchyma
1. Thickening	The cell walls are uniformly thickened.	The cell walls get extra thickened at places.
2. Mechanical tissue	Parenchyma does not have any permanent mechanical function except when its cells are turgid.	It is a living mechanical tissue.
3. Presence	Parenchyma is found both in the outer and inner parts of plant organs.	It is mostly restricted to outer parts of plant organs.

Table 6. Differences between Collenchyma and Sclerenchyma.

Characters	Collenchyma	Sclerenchyma
1. Nature	Living mechanical tissue.	Non-living mechanical tissue.
2. Thickening on cell wall	Due to deposition of cellulose, hemicellulose and pectin.	Due to deposition of lignin.
3. Water contents in cells	High	Low.
4. Lumen of cell	Big	Small or absent.
5. Refractive index	High	Low.
6. Photosynthesis	Possible	Not possible.
7. Branching of cells	Never branched.	Can show branching.
8. Texture	Keeps the organs soft	Makes the organs hard.

Table 7. Differences between Xylem and Phloem.

Characters	Xylem	Phloem
1. Mechanical support	Mechanical tissue.	Not a mechanical tissue.
2. Conduction	Xylem conducts water and minerals.	Phloem conducts organic food.
3. Depth	Xylem lies deeper in plant organs.	Phloem is situated towards outer side.
4. Structure	Made up of tracheids, vessels, xylem parenchyma and xylem fibres.	Made up of sieve tube members, companion cells, phloem parenchyma and phloem fibres.
5. Living/dead	Tracheids, vessels and xylem fibres are dead. Xylem parenchyma is living.	Sieve tube members, companion cells and phloem parenchyma are living and phloem fibres are dead.

Table 8. Differences between Shoot apex and Root apex.

Characters	Shoot apex	Root apex
1. Position	Shoot apex is apical in position.	Root apex is subterminal in position.
2. Protection	Shoot apex is protected by young leaf primordia.	Root apex is covered by root cap which protects the root from withering effect of soil particles.
3. Differentiation	Shoot apex is differentiated into two regions—**tunica** and **corpus**.	Root apex is differentiated into three regions *i.e.* Protoderm, Cortical initials and Vascular cylinder.
4. Primordia	From shoot apex leaf like primordia **arise**.	From root apex no primordia arise.
5. Flowering	Shoot apex shows changes during flowering.	Root apex does not show changes during flowering.
6. Quiscent centre	Shoot apex has no quiescent centre.	Root apex has quiescent centre.

Table 9. Differences between Tracheids and Vessels.

Characters	Tracheids	Vessels
1. No. of cells	It is unicellular.	It is multicellular.
2. Size	It is a fraction of a centimetre.	It is several centimetres long.
3. Ends	The ends are tapering or oblique.	The ends are rounded or transverse.
4. Septa	The septa between tracheids are intact.	The septa between adjacent cells are lost.
5. Lumen	The lumen is narrow.	Their lumen is wide.
6. Thickness	Their walls are more thick.	Their walls are less thick.

Table 10. Differences between Fibres and Sclereids.

Characters	Fibres	Sclereids
1. Shape	Fibres are elongated.	Sclereids are broad.
2. End walls	They have tapering end walls.	The end walls are blunt.
3. Branching	They are generally unbranched.	They are unbranched or branched.
4. Pits	The pits of fibres are narrow and unbranched.	The pits are deep and branched.
5. Origin	They originate from meristematic cells.	They are formed secondarily by the thickenings of parenchyma cells.

PRACTICE PROBLEMS – TISSUES

1. Write the functions of parenchyma.
2. Write the functions of collenchyma.
3. Describe the functions of sclerenchyma.
4. Give any four examples of secondary meristem.
5. Desribe briefly the tunica-corpus theory.
6. What is intercalary meristem? How it can be differentiated from other meristems?
7. What is wood? What are the components of wood? Name two types of wood.
8. Write briefly about laticiferous tissues.
9. What you know about glandular tissues?
10. Differentiate between vessel and sieve tube.

ANSWERS TO PRACTICE PROBLEMS

1. **Functions of parenchyma**
   1. The most important function assigned to these cells is **storage.**
   2. The chlorenchyma takes part in photosynthesis.
   3. Parenchyma helps the plant in floating.
   4. In the fleshy stem and leaves, parenchyma cells store water.
   5. They provide rigidity.
   6. Parenchyma may become meristematic and help in wound healing, regeneration and grafting.
2. **Functions of collenchyma**
   1. The most important functions of collenchyma is to provide support for both growing stem and leaves.
   2. It carries the process of photosynthesis in plants where chloroplasts are present in collenchymatous cells.
   3. In certain cases they regain the power to divide.
3. **Functions of sclerenchyma**
   1. The fibres serve as supporting elements in plant parts.
   2. The presence of fibres on the surface of seeds and fruits help in dispersal by wind.

4. **Examples of secondary meristem**
   1. Cambium of root
   2. Cork cambium of root
   3. Cork cambium of stem
   4. Interfascicular and fascicular cambium of stem.
5. **Tunica-corpus theory.** Schmidt proposed the Tunica-Corpus Theory (1924) to explain the structure of apical meristem. He explained that intercalary meristem differentiated into a central mass of undifferentiated large cells called **corpus** and outer layer of small cells called **tunica.** The cells of tunica undergo **anticlinal** divisions while the cells of corpus divide in different planes to produce procambium, cortical cells and leaf primordia.
6. **Intercalary meristem.** The intercalary meristems are internodal in their position. It is merely a position of apical meristem that has become separated from the apex during development. Intercalary meristem is also found at the base of leaves of grasses. **Difference from other meristem.** It is present only in a few plants. Intercalary meristem is enclosed within masses of permanent tissue while the other meristems are not covered by permanent tissue.
7. Wood is a product of metabolism of plants with unique renewable resource and of great value. It forms the bulk of the body of tree. It is important renewable raw material.
   Technically, wood is secondary xylem formed by vascular cambium during secondary growth.
   Components of wood. Tracheary elements (vessels and tracheids), fibres and axial parenchyma cells of xylem produced by **fusiform initials** are the main components of wood. Ray initials produce cells horizontal to the longitudinal axis of the stem rays.
   Types of wood
   (1) **Soft wood** and **hard wood** produced by gymnosperms and dicots respectively.
   (2) **Sap wood** (living) and **heart wood** (dead).
8. **Laciceferous or Laticiferous tissues of Laticifers.** It is concerned with secretion of **latex** or an emulsion or oils, alkaloids, resins, proteins and sugar. It consists of thin walled, elongated branched **ducts.** The laticifers are of two types (a) **Latex vessels (b) Latex cells.** These occur irregularly distributed in the **mass of parenchymatous cells.**
   (a) **Latex cells** are called **simple laticifers** or **non-articulated laticifers** which may be unbranched or may be branched profusely but **do not fuse** together to form a network quite common in the members of families **Apocynaceae, Asclepiadaceae, Euphorbiaceae** and **Moraceae** *(e.g.* milkweed, *Euphorbia, Ficus* etc.*).*
   (b) **Latex vessels (Articulated laticifers)** are formed by union of latex cells (hence called **compound Laticifers also),** are quite common in family **Papaveraceae** (poppy family), **Caricaceae** (papaya family), **Compositae, Musaceae** (banana family)
9. **Glandular tissue.** They are isolated secretory structures which may be unicellular or multicellular. **Example**—(i) **Nectar secreting** glands.
   (i) **Nectar** (or honey) is a sugary substance secreted by **nectar gland** or **nectaries** which may be **floral** (present in flower) or **extra floral** (on vegetative parts).
   (ii) **Water-secreting structures (Water stomata or hydathodes)** are present along the margins and apices of leaves. The exudation of water through these is called **guttation.**
   (iii) **Osmophores.** They secrete essential oil.
   (iv) **Chalk or gland** cells secrete salts *e.g. Tamarix.*
10. **Differences between Vessel and Sieve tube.**

Character	Vessel	Sieve tube
1. **Function**	Water or sap conducting channel.	Food conducting channel.
2. **Structure**	Made of dead and empty cells.	Made up of living but denucleated cells.
3. **Thickness of walls**	Thick	Thin
4. **Lignin**	Present on vessel walls.	Absent
5. **Mechanical strength**	Provided by vessel.	Not provided.
6. **Septa**	Septa between adjacent vessels degenerate.	Septa bear pores and form sieve plates.

ADDITIONAL USEFUL INFORMATIONS ABOUT TISSUES FOR COMPETITIVE EXAMINATIONS

- *The word stele was coined by* ***Tiegham.***
- *In sugarcane, there is no distinction of tunica and corpus.*
- *Reproductive apex is elongated in* ***Sagittaria*** *but can go up to 400 times broad in* ***Chrysanthemum.***
- *Leaf gap is the gap of vascular supply due to the passage of leaf trace in the stele.*
- ***Nageli*** *(1858) coined the term meristem.*
- ***Amphicribal*** *vascular bundles are also known as* ***ectophloic*** *or* ***hadrocentric.***
- *Calotropis bears included phloem.*
- ***N. Grew*** *(1862) is known as father of* ***Plant Anatomy.*** *He coined the terms tissue and parenchyma.*
- *Sieve cells/sieve tube elements resemble RBCs in being without nucleus in mature state.*
- ***Strasburger discovered albuminous cells instead of companion cells in phloem.***
- *Sieve tube elements and companion cells are known as sister cells as they are formed due to division of same mother cells.*
- ***Hartig*** *(1837) discovered sieve tubes.*
- ***Sanio*** *(1863) coined the term tracheid.*
- *Vessels have been reported is some plants of pteridophytes e.g.* ***Selaginella, Marsilea.***

THE TISSUE SYSTEM

Depending upon the plant organ, various tissues are distributed in characteristic patterns within the plant body. Plant tissues are constituted of three basic types of system :

(i) Epidermal (ii) Ground or **fundamental and (iii) Vascular.**

Epidermis etc. which are protective in function form the **dermal system. Vascular system** is made up of tissues like xylem and phloem which mainly perform the function of conduction. **Ground** or fundamental system of tissues constitute all other type of tissues excluding dermal and vascular as parenchyma, collenchyma, sclerenchyma etc.

(i) Epidermal tissue system. Epidermal tissue system constitutes the outermost covering of whole plant body and includes :

(a) Epidermis

(b) Stomata

(c) Trichomes and hairs (epidermal appendages)

(a) Epidermis. Epidermis is the outermost layer of all organs of primary plant body. Usually, it is made up of single layer of cells. However in some plants it is multi-layered e.g. leaf of *Nerium*. The epidermis of root differs in origin, structure and function and called as **epiblema** or **piliferous layer.** It is made up of elongated, compactly arranged cells. Cells constituting epidermal cells are parenchymatous with little quantity of cytoplasm lining the cell wall with a large vacuole.

The outer wall of epidermal cells contain a falty substance called cutin and form **cuticle** on the epidermis. On the surface of cuticle, a waxy coating may also be present.

(b) Stomata. These are structures present in the epidermis of leaves.

Stomata help in gaseous exchange at the time of respiration and photosynthesis. They are minute pores found in the epidermis of leaves, stem etc. Stomatal transpiration takes place through stomata. There are two kidney shaped **guard** cells which bound a minute elliptical pore in a stoma. The guard cells are modified epidermal cells. The wall of guard cells near the pore is thick (Fig. 16). The outer wall is thin, elastic and semipermeable.

In monocots the guard cells are **dumb-bell** in outline. The guard cells are filled with chloroplasts. Both kidney shaped and dumb-bell shaped guard cells have been reported in *Cyperus*. Sometimes, immediate cells surrounding the guard cells differ from other epidermal cells and are called as **subsidiary** or **accessory cells.** Average length of stomata is 20 to 28 µm and breadth 5 µm.

(c) Trichomes and hairs. Number of hairs may be present on epidermis. The root hairs are unicellular and represent the extension of epidermal cells. On stem epidermal hairs are called as **trichomes.** In shoot system they are usually multicellular. They may be soft or stiff, branched or unbranched. Some times, they are secretory. They help in retarding the rate of transpiration. Root hairs help in absorption of water and minerals from soil.

(ii) Ground tissue system. Ground or fundamental system of tissues constitute tissue excluding dermal and vascular like parenchyma, collenchyma, sclerenchyma. Cortex, pericycle, pith and medullary rays, primary stems and roots usually contain parenchymatous cells. **Mesophyll** is present in ground tissue of leaf and made up of thin walled chloroplast containing cells.

(iii) Vascular tissue system

On the basis of the orientation of the xylem and phloem, the individual vascular bundles of the stele are classified as collateral, bicollateral and concentric. If the bundles contain cambium, they are said to be **open**, but if no cambium develops, they are referred to as **closed**.

(a) The collateral bundle (Fig. 17B) is characterized by having the protoxylem and the protophloem located on the same radius of the stem. Collateral bundles are characteristic of the stems of dicotyledons and gymnosperms.

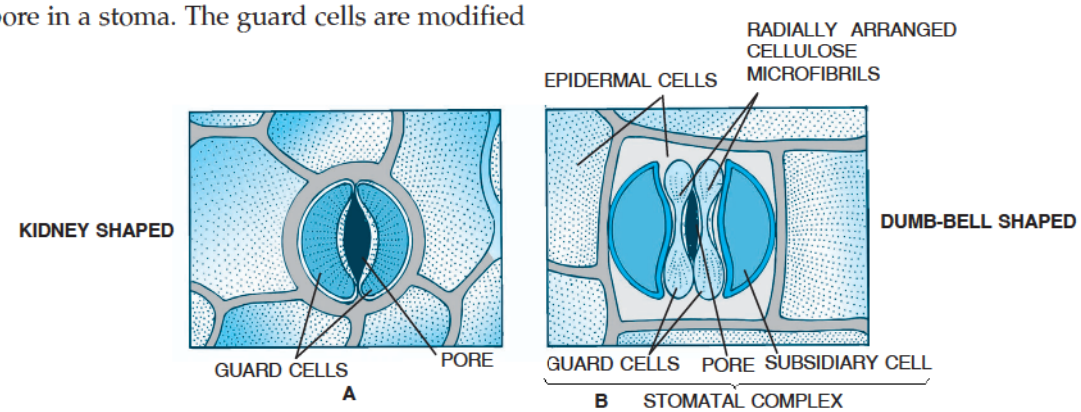


Fig. 16. A. A dicot stoma with kidney shaped guard cells and; **B.** A monocot stoma with dumb-bell shaped guard cells.

Table 11. Differences between Collateral and Bicollateral bundles.

Characters	Collateral bundle	Bicollateral bundle
1. Phloem	Present in single strip.	Present in two strips.
2. Position of phloem	Towards outside xylem on same axis.	On both inner and outer sides of xylem on the same axis.
3. Cambium	Open collateral bundle bears one strip of cambium	Open bicollateral bundle bears two stirps of cambium.

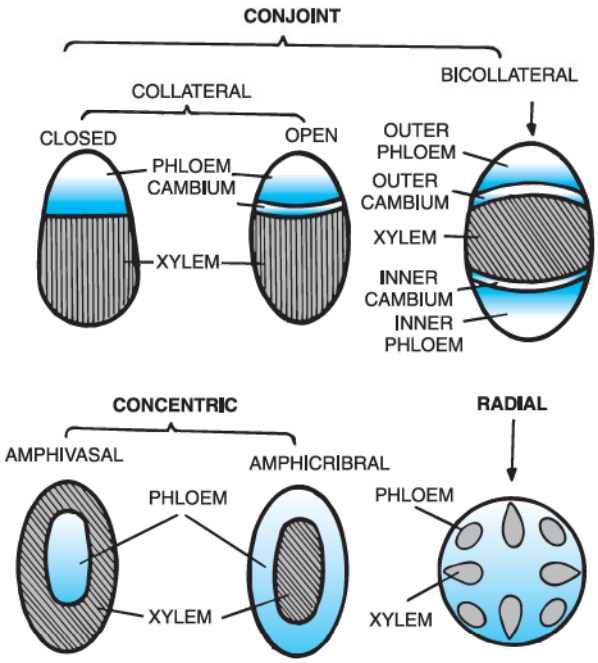


Fig. 17. Different types of vascular bundles.

(b) The bicollateral bundle (Fig. 17C) has the same general features as the collateral bundle, but phloem is located both internally and externally to the xylem. The cambial layer occurs only between the xylem and the outer mass of phloem. All tissues lie on the same radius. Bicollateral bundles are found in the stems of certain ferns and in members of the Cucurbitaceae family.

(c) The concentric bundle. When either one of the vascular tissues surrounds the other, the bundle is called **concentric**. If the phloem surrounds the xylem, the bundle is **amphicribral** (Fig. 17 D), but when the xylem surrounds the phloem, it is **amphivasal** (Fig. 17E). Amphicribral bundles are found in some of the ferns, and amphivasal bundles in the underground stems of some monocotyledons.

The radial arrangement of xylem and phloem. While the primary vascular tissue of the stems of plants most often is arranged in separate vascular bundles, the roots of plants show no such structure. Instead, the protoxylem and protophloem points are located on separate radii, and hence have most often been referred to as radial in arrangement.

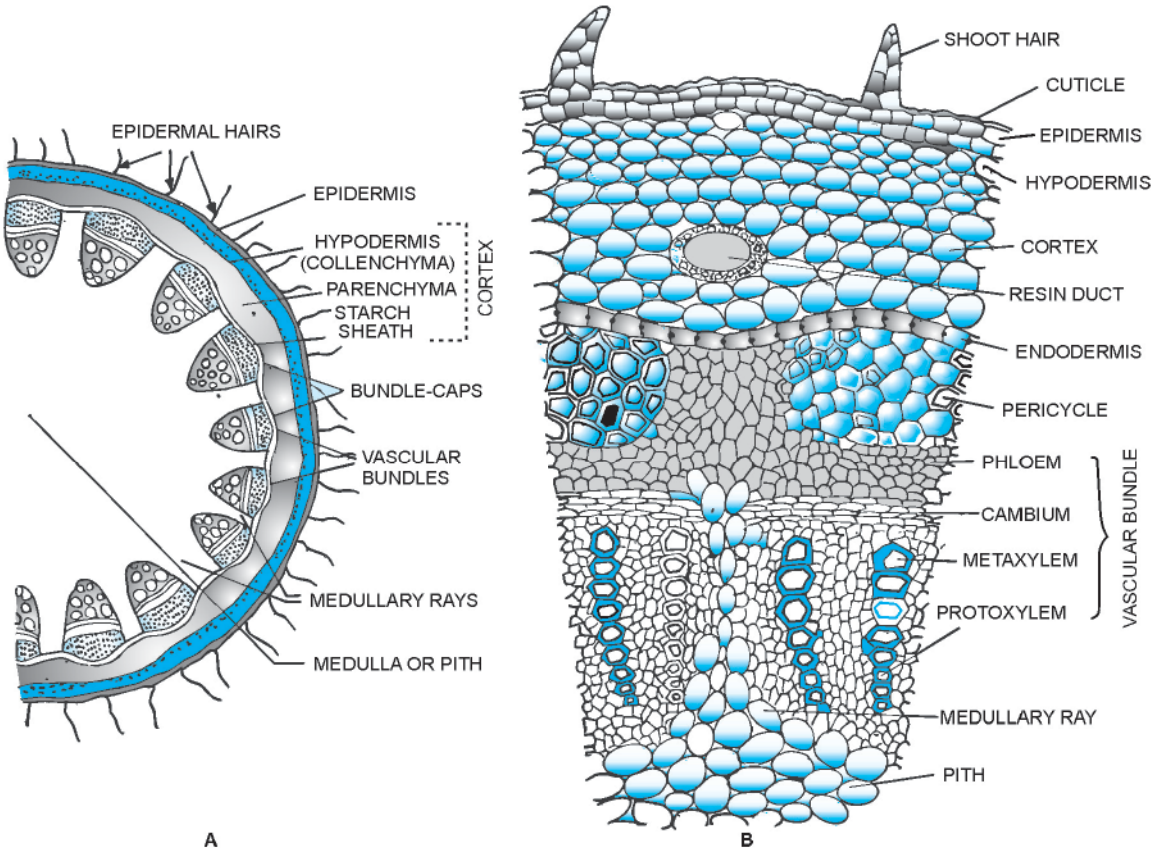


Fig. 18. T.S. Young dicot stem; **A.** Diagrammatic; **B.** A sector in detail showing cellular view.

ANATOMY OF DICOTYLEDONOUS AND MONOCOTYLEDONOUS PLANTS

INTERNAL STRUCTURE OF YOUNG DICOT STEM

T.S. Young stem of Sunflower

Internal structure of young (primary) stem shows the presence of three tissue systems :

(a) Dermal or epidermal tissue system *e.g.* epidermis.

(b) Fundamental or ground tissue system *e.g.* cortex, pericycle, pith and medullary rays.

(c) Vascular or fascicular tissue system *e.g.* vascular bundles.

Dermal or epidermal tissue system which is normally made up of single layered epidermis and is differentiated from tunica of shoot apical meristem.

1. Epidermis. It is the outermost layer of stem and made up of compactly arranged, thin walled parenchymatous cells. On outer side, it is covered by cuticle which is made up of cutin, a fatty substance. Cells constituting epidermis lack intercellular spaces. Cuticle reduces the loss of water from the surface of stem. The epidermis bears minute pores called stomata. Each stoma is made up of two kidney shaped guard cells which contain chloroplasts. The epidermis exhibits several unbranched, multicellular hairs which protect the stem against excessive heating and sudden variations in temperature.

2. Cortex. It extends immediately beneath the epidermis to the vascular tissue. The outermost part of cortex next to epidermis is called as **hypodermis**.

(a) Hypodermis. Hypodermis in dicot stem is made up of a few layered collenchymatous cells (Fig. 18). They are living cells and contain chloroplasts. The cells are angular and bear cellulose and pectin thickenings. The main functions of hypodermis are :

(i) To provide mechanical strength.

(ii) Storage of food.

(iii) Photosynthesis.

(b) Cortex (general). It lies between the hypodermis and endodermis and is made of loosely arranged parenchymatous cells with intercellular spaces. The cells are isodiametric in shape and may contain chloroplasts. Inside the cortex a number of oil ducts are present. Each oil duct has a hollow cavity surrounded by small, densely protoplasmic **glandular cells.** The main functions of cortex are :

(i) Storage of food.

(ii) Young green cells of cortex carry out photosynthesis.

(c) Endodermis. Endodermis is the innermost limiting layer of cortex which separates the vascular tissue from cortical cells. It is uniseriate, wavy layer composed of modified parenchymatous cells which are compactly arranged and without any intercellular spaces. Endodermis is made up of vertically elongated cells which appear barrel shaped in cross-section. In some dicotyledonous angiosperms, the endodermal cells bear characteristic thickening on their walls, the **casparian thickenings.** The thickenings are restricted to radial and inner tangential walls. In sunflower stem, starch grains are found in this layer and is also called as starch sheath. The function of storage is attributed to endodermis in sunflower, because it contains starch grains.

3. Pericycle. The layers of cells which occur inner to the endodermis and outer to the vascular tissue form the pericycle. Pericycle is made up of both sclerenchymatous and parenchymatous cells present in alternate patches. Sclerenchyma fibres are found just outer to vascular bundles forming a bundle cap. The parenchymatous cells of pericycle function as food storage tissue and the sclerenchyma provides mechanical support.

4. Vascular tissue. Vascular tissue is made up of a number of vascular bundles and are arranged in a ring. A vascular bundle is also called **fascicle**. The primary vascular bundle develops from procambium. In T.S. vascular bundles appear wedge shaped having xylem towards inner side and phloem towards outer side. The vascular bundles are **conjoint**, **collateral** and **open**. Vascular bundles, when xylem and phloem combine into one bundle and occur on the same radius are called conjoint. Collateral vascular bundles are with xylem being internal and phloem external. A collateral bundle is open, when cambium is present. In some plants belonging to the family *Cucurbitaceae*, *Apocynaceae* and *Asclepiadaceae*, vascular bundles are **bicollateral** (Fig. 17C) showing the two phloem patches, one on outer side and the other on inner side of xylem known as external phloem and inner phloem.

The phloem of each bundle consists of sieve tubes, companion cells, phloem parenchyma and often phloem fibres. The sieve tubes consist of thin walled elongated cells arranged in vertical rows. The transverse septa between these are perforated and are known as sieve plates. Sieve tube in young condition may contain scanty cytoplasm and nucleus. Nucleus and cytoplasm are lost in sieve tubes. On maturity associated with sieve tubes are smaller cells called companion cells. The phloem parenchyma are like normal parenchyma cells present in between the sieve elements.

The **cambium** is a band of thin walled cells lying between phloem and xylem. Cambium retains its meristematic nature. The cells constituting the cambium are thin walled, rectangular as seen in cross section, with prominent nucleus and dense cytoplasm. By the rapid divisions in cambial cells, secondary phloem and secondary xylem are added during secondary growth.

The xylem is made up of vessels, tracheids, xylem fibres and xylem parenchyma.

The wood or xylem fibres along with tracheids and vessels serve as mechanical tissues for support. The protoxylem lies towards the inner side of stem bundle next to pith. Such condition of xylem is called **endarch**. Protoxylem is the first xylem to be differentiated from

procambial strands lying next to pith in stem. The cells constituting the protoxylem are smaller in diameter than those of xylem developed later (metaxylem). The cells of metaxylem are not only larger but also thicker walled than protoxylem being more lignified. The protoxylem and metaxylem together constitute the primary xylem. Vessels and tracheids constituting the primary xylem are present in **radial rows** and are angular or **polygonal** in outline. Tracheids and vessels in protoxylem are with annular and spiral thickenings while metaxylem has pitted thickenings.

The functions of vascular bundles are conduction of food and water and to provide mechanical strength to the organ.

5. Primary medullary rays. The ground tissue found in between the vascular bundles is called medullary ray. It is made up of parenchyma cells which are thin walled, radially elongated and connect the pith with pericycle. Medullary rays are involved in radial conduction of food and water.

6. Pith or **medulla.** Pith is the ground tissue present in the centre. Pith is made up of large parenchymatous cells with intercellular spaces. They are often filled with starch grains and other foods. The function of the pith is to store the food.

INTERNAL STRUCTURE OF MONOCOT STEM

T.S. Monocot Stem of Maize

A thin transverse section of monocot stem of maize shows the following structure :

1. Epidermis. It is the outermost layer and made up of parenchymatous cells. The outer walls of the cells are cutinised forming a thick cuticle. The continuity of this layer may be broken here and there by the presence of few stomata.

2. Hypodermis. Hypodermis is made up of 2-3 layers of sclerenchymatous cells. The cells constituting the hypodermis are lignified and in crosssection appear polygonal in shape. Hypodermis gives mechanical strength to the stem.

3. Ground tissue. It is the mass of parenchymatous, thin walled cells, extending from below the sclerenchyma to the centre. The cells are loosely arranged and contain intercellular spaces. In monocot stems, ground tissue is not differentiated into cortex, endodermis, pericycle etc. The vascular bundles are embedded in this region (Fig. 19 A, B).

4. Vascular system. Vascular bundles are collateral and closed. A bundle lacking cambium is called closed. The vascular bundles lie scattered in the ground tissue **(atactostele)**. They are more numerous and lie closer together nearer the periphery than the centre. The vascular bundles are almost oval in outline. The vessels of xylem are arranged in the form of 'V' (Fig. 20 B). The divergent ends of 'V' are occupied by two big, oval metaxylem vessels with pitted thickenings. Tracheids lie irregular in between them. The protoxylem is positioned radially towards the centre. Thus xylem is endarch, protoxylem is mainly formed of two smaller (annular and spiral) vessels.

Xylem fibres and xylem parenchyma are present just outside the protoxylem. A **lysigenous cavity** develops just below the protoxylem. Actually it is formed by rupturing of inner protoxylem elements.

Phloem is exclusively composed of sieve tubes and companion cells. Phloem parenchyma and phloem fibres are absent. Phloem can be distinguished into an outer crushed protophloem and an inner metaphloem. Metaphloem is the functional part of phloem in mature vascular bundle.

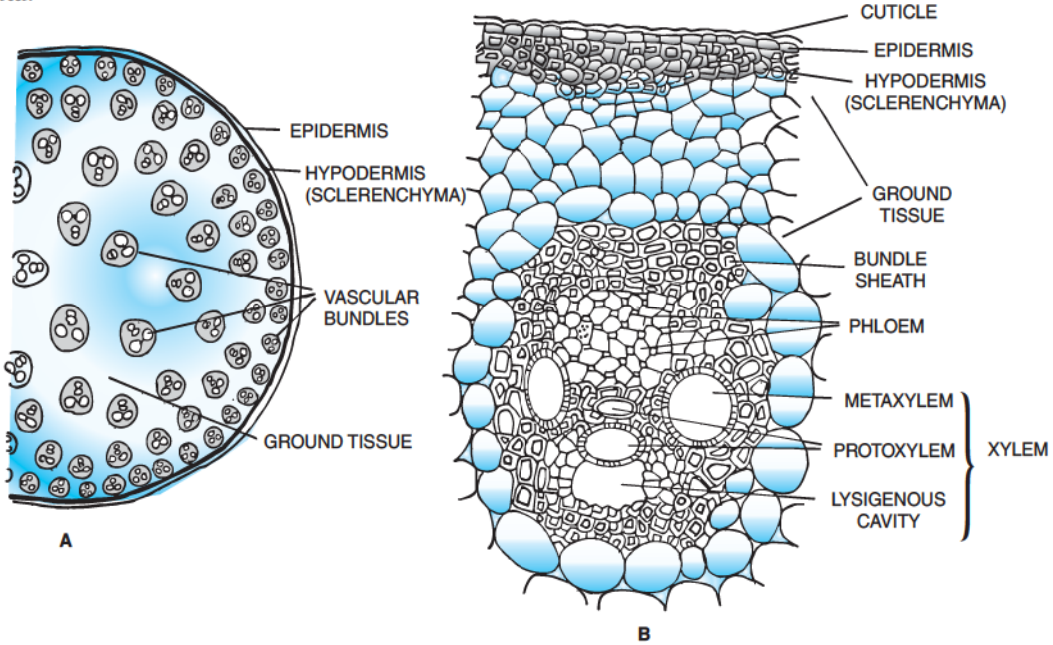


Fig. 19. T.S. Monocot stem: **A.** Diagrammatic; **B.** A sector showing details.

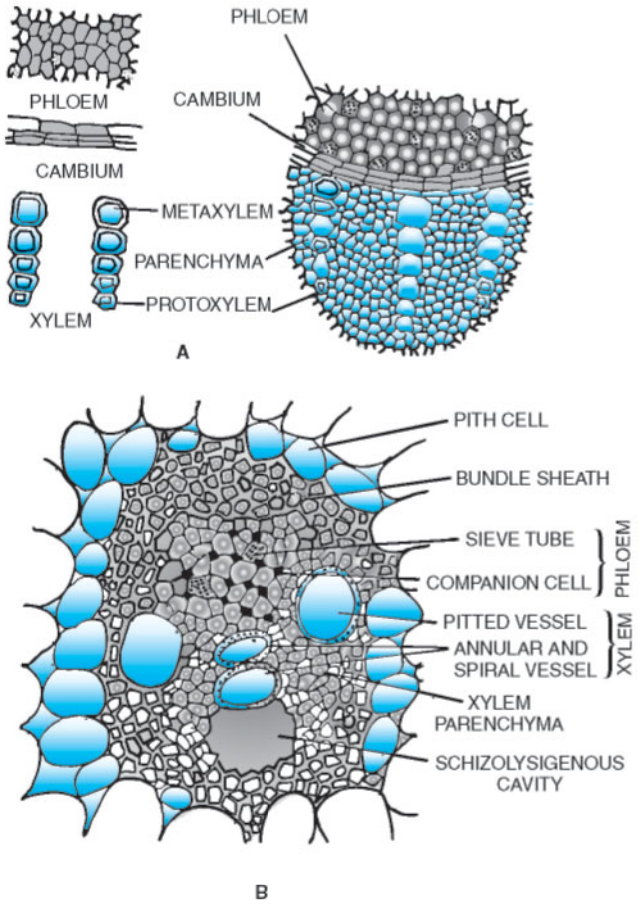


Fig. 20. A. T.S. vascular bundle of young dicot stem; **B.** T.S. vascular bundle of monocot stem.

SECONDARY GROWTH (SECONDARY THICKENING IN DICOT STEM)

The development of primary tissues causes stem to grow in length and only up to some extent in thickness. In dicots, particularly in woody plants, growth in diameter is brought about by development of secondary tissues. Secondary tissues in stem are derived by the activity of cambium. There are two principal types of secondary tissues found in the stems of dicotyledonous plants, viz., **secondary vascular tissues** and **periderm**. Secondary growth occurs in dicotyledons and gymnosperms. A special type of secondary growth also occurs in some monocotyledons as exception which leads to increase in thickness.

Secondary vascular tissues

(i) Cambium. The secondary growth is initiated by vascular cambium. A strip of cambium called **intrafascicular** cambium is present in between phloem and xylem of conjoint and collateral bundle of dicot stems. Such vascular bundles are called open. This turns into a continuous ring, when another strip of **interfascicular** cambium (Fig. 23) develops between the region of parenchyma between the vascular bundles. Interfascicular cambium is of secondary origin. The new cells formed by the division of cambium differentiate into secondary xylem (Fig. 22), which becomes continuous with primary xylem and secondary phloem, which becomes continuous with primary phloem. These additions of secondary phloem and secondary xylem cause the stem to increase in diameter. The vascular cambium is made up of two types of cells *i.e.* spindle shaped elongated cells called **fusiform initials** and smaller and isodiametric cells called **ray initials** (Fig. 21). Fusiform initials form secondary xylem on inner side and secondary phloem towards outer side. The ray initials give rise to xylem rays and phloem rays *i.e.* secondary medullary rays.

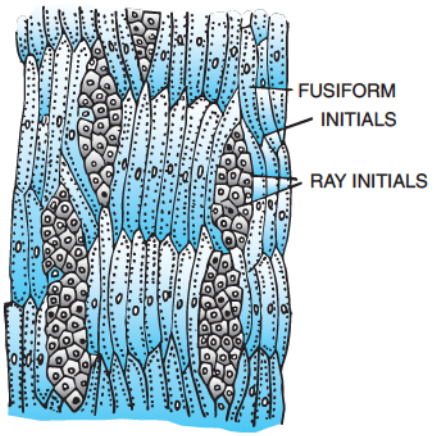


Fig. 21. Cambium showing fusiform initials and ray initials.

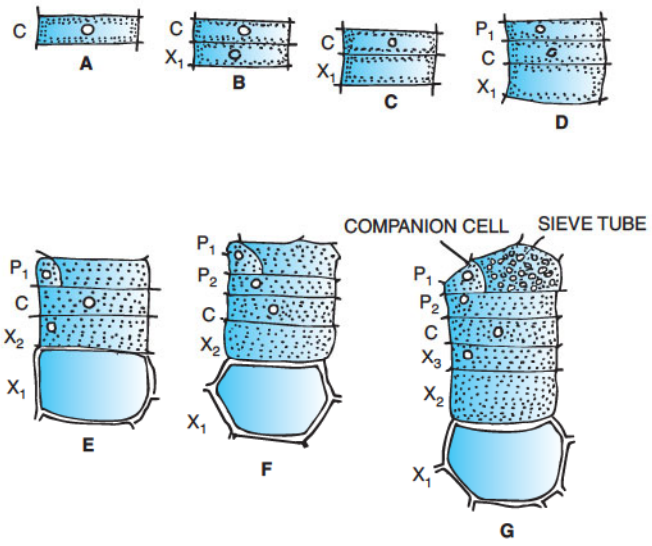


Fig. 22. Formation of secondary xylem and secondary phloem by cambium cells.

(ii) Secondary phloem. Secondary phloem (Fig. 23) develops on the outer side of vascular cambium. As the secondary phloem develops, it pushes and finally crushes the primary phloem. Secondary phloem is constituted of sieve tube cells, companion cells, phloem parenchyma and phloem fibres.

(iii) Secondary xylem. Secondary xylem is produced towards inner side of vascular cambium and presses the primary xylem towards centre without its obliteration. Secondary xylem is made up of vessels, tracheids, wood parenchyma and wood fibres. The secondary growth is characterised by formation of **annual rings**, evident in secondary xylem. The secondary xylem elements formed during spring are large, thin and broad as compared to those formed during autumn being small, narrow and thick. As a result **spring wood** (secondary xylem formed during spring) and **autumn wood** (secondary xylem formed during autumn) are sharply demarcated. In T.S. of stem these two types of woods appear in the form of distinct concentric circles called annual rings (Fig. 24). Spring wood and autumn wood of every year constitute an annual ring. In this manner, every year such rings appear and their identity is well marked. The number of annual rings corresponds to its age of tree. **Dendrochronology is the branch of anatomy which deals with determining the age of a tree.**

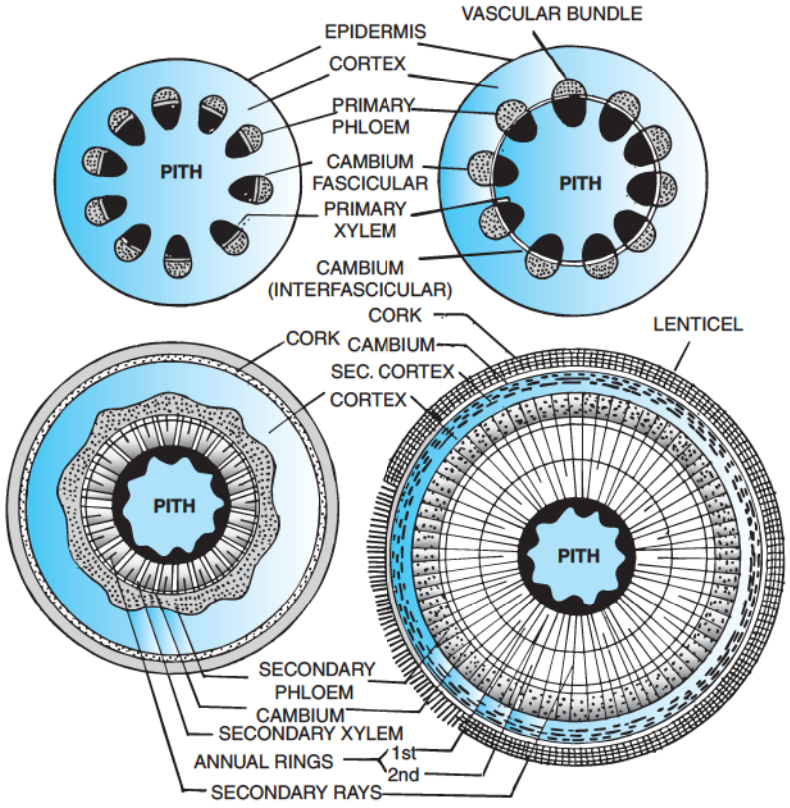


Fig. 23. Secondary growth in dicot stem (diagrammatic) stages in T.S.

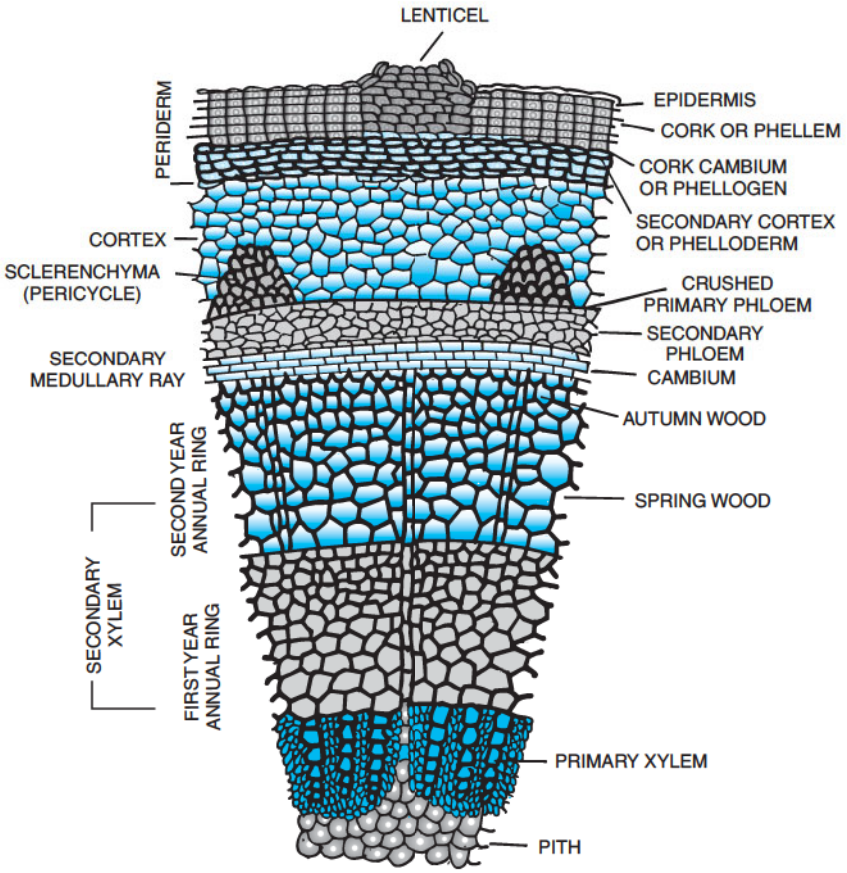


Fig. 24. T.S. dicot old stem showing secondary growth.

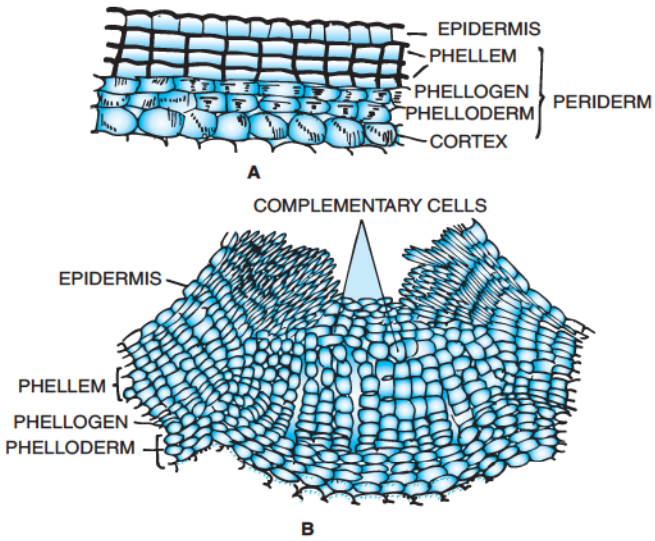


Fig. 25. A. Periderm formation; **B.** L.S. Lenticel.

Activity of cork cambium

Periderm

A similar secondary growth takes place outside the vascular bundles, which leads to the formation of periderm. It consists of :

(i) Phellem or cork.

(ii) Phellogen or cork cambium.

(iii) Phelloderm or secondary cortex.

The **phellogen** or cork cambium (Fig. 25) appears below the epidermis in any region extending up to endodermis. The cells are cut off on outer as well as inner side of cork cambium. The outer cells form **phellem** or cork. The cells constituting the cork are rectangular, in radial rows and with loose protoplast and suberised walls. Cells formed on inner side of cork cambium constitute secondary cortex or **phelloderm**. Lenticels develop on phellem. Here the cells are loose,

Table 12. Differences between Periderm and Bark.

Characters	Periderm	Bark
1. Constitution	Periderm constitutes cork cambium (phellogen), cork (phellem) and secondary cortex (phelloderm).	Bark constitutes the epidermis, cork etc. lying outside the cork cambium.
2. Dead cells	In periderm only cork is dead.	In bark all the cells are dead.
3. Nomenclature	Periderm is scientific and technical name.	Bark is non-technical and common term.

thin walled parenchymatous with many air spaces. They often project slightly above the outer surface of the stem.

Bark

All the dead cells lying outside the phellogen constitute the bark of plant. Thus it may include the epidermis, cork, hypodermis and even part of cortex depending upon the position of origin of cork cambium or phellogen. Bark is protective in nature. It is insect repellant and also acts as a heat screen. Bark of *Cinchona* secretes the drug **quinine.**

ANOMALOUS SECONDARY GROWTH

In some plants like *Aristolochia*, *Bougainvillea* secondary growth does not occur as described above. The deviating types of secondary growth are called anomalous secondary growths.

WOOD

The importance of wood to the mankind is next only to food and clothing. Processed and unprocessed wood finds several uses in our day to day life. Wood is a source of timber, fuel, shelter, tools and furniture. It is one of the main products of metabolism of trees and constitutes the bulk of their body. Wood is stiff, strong, hard and tough material. It is an important renewable natural resource and had been in use even before metals were discovered. Egyptians built ships from Cedar wood got from Lebanon in 400 B.C. As a raw material for construction purposes, it is highly versatile.

Botanically, term wood is used for secondary xylem produced due to activity of cambium in the stems of gymnosperms and dicotyledonous angiosperms. Vascular cambium is a lateral meristem whose activity leads to an increase in the thickness or girth of stem and root. The vascular cambium is made up of two types of cells (i) the fusiform initials and (ii) the ray initials (Fig. 21). The fusiform initials when examined in longitudinal section are elongated prosenchymatous cells. These cells constitute the **axial system** of secondary vascular tissue. They take part in the formation of sieve tubes, companion cells, phloem parenchyma, phloem fibres, tracheids, vessels, xylem fibres and xylem parenchyma. Ray initials are small isodiametric cells, which after division give rise to **radial system** of vascular tissue and produce cells horizontal to the longitudinal axis of stem *e.g.* the phloem rays and xylem rays.

(i) Soft wood and hard wood

The secondary xylem or wood produced by gymnosperms is commercially called soft wood. Truly speaking coniferous wood is very hard. Soft wood lacks the vessels in xylem and is also called as **non-porous** wood.

In angiosperms (dicotyledonous trees) wood is said to be hard or **porous**. It is mainly made up of vessels. Soft wood and hard wood can easily be distinguished by a hand lens by examining T.S. of a log. Soft woods are made up of 90-95 percent tracheids and remaining 5-10 per cent is made up of ray cells. Hard wood is made up of vessels, xylem fibres and xylem parenchyma.

(ii) Sap wood and heart wood

When youngest or latest formed secondary xylem present towards periphery of stem functions most actively in conduction and food storage, it is called **sap wood** (Fig. 26). It is living and lighter in colour. The older wood of annual rings in the centre, which is comparatively darker become stained due to deposition

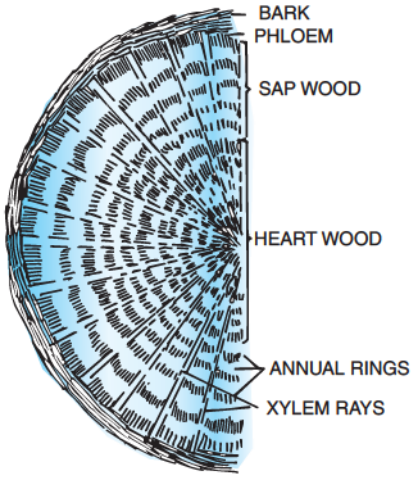


Fig. 26. Sap wood, heart wood and annual rings.

of aromatic substances, oils, resins, gums, tannins etc. represent **heart wood**. The cavities in heart wood are often clogged with deposits of gummy materials and **tyloses** (Fig. 27). In some cases heart wood dries out, still in others it remains wet. Heart wood is more durable timber than sap wood and in general commercially more valuable than sap wood. Heart wood is more resistant to micro-organisms and insects than sap wood. Substances present in heart wood are collectively called as **extractives.**

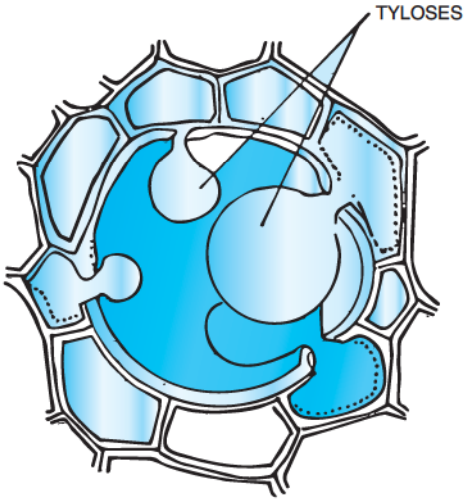


Fig. 27. Tyloses in xylem.

ADDITIONAL USEFUL INFORMATIONS ABOUT ANATOMY OF STEM FOR COMPETITIVE EXAMINATIONS

- *Medullary vascular bundles are found in stem of* ***Mirabilis.***
- *Heartwood is most abundant in Mulberry but absent in Poplar and willow.*
- *Most durable soft wood is a* ***Cedrus deodara.***
- *Most durable wood is of teak (****Tectona grandis****).*
- *Lightest wood is* ***Ochroma lagopus.***
- *Heaviest wood is* ***Guaicum officinale.***
- *Dicot showing atactostele is present in* ***Amaranthus.***
- ***Aristolochia*** *and* ***Bougainvillea*** *show anomalous secondary growth.*
- *Number of annual rings decrease as they proceed from base to the top of tree.*
- *Epidermal cells containing cystoliths are called* ***lithocysts.***
- *In grasses and* ***Equisetum*** *(a pteridophyte), silica is present in epidermal cells.*
- *The various biochemical substances deposited in tracheary elements are called* ***extractives.***
- *Cambium may form parenchyma in interfascicular region between the two vascular bundles e.g. Vitis, Aristolochia, Clematis, Bauhinia, Tinospora.*
- *Cambium forms unusual proportion of secondary xylem and secondary phloem e.g. Bignonia, Doxantha.*
- *Cambium forms patches of parenchyma in secondary xylem e.g. Urtica dioca.*
- *Successive rings of cambia are formed in Boerhaavia, Bougainvillea, Mirabilis jalapa.*
- *Interxylary phloem is formed in Leptadenia, Salvadora.*
- ***Dendrochronology*** *is the study of age of tree/timber.*

(iii) Early wood and late wood

Spring wood is also called as **early wood**. Secondary wood formed during the favourable seasons of spring and summer is profuse and consists of large vessels with wider lumen. Similarly in autumn or winter climatic conditions being adverse, the activity of cambium is poor and secondary wood formed is non-profuse and the vessels and tracheids produced are smaller, wood is called **late wood** or **autumn wood**. These two types of woods (early and late) in transverse section of stem appear in the form of distinct concentric rings called annual rings. Each annual ring corresponds to one year.

(iv) Ring porous and diffuse porous wood

In woody trees like *Tilia* found in temperate regions with distinct summer and winter seasons, annual rings exhibit distinct and prominent vessels in early or spring wood and narrow ones in late or autumn wood. Thus, the wood represent large and smaller vessels in distinct regions of an annual ring. The wood in such cases is said to be **ring porous** (Fig. 28). However, in tropics, with not sharp distinction of seasons, xylem vessels of almost equal size are uniformly distributed throughout spring and autumn wood. Such a wood is called **diffuse porous**. In few plants intermediate forms of wood has also been noticed. The ring porous type of wood is said to be more advanced than diffuse porous from phylogenetic point of view.

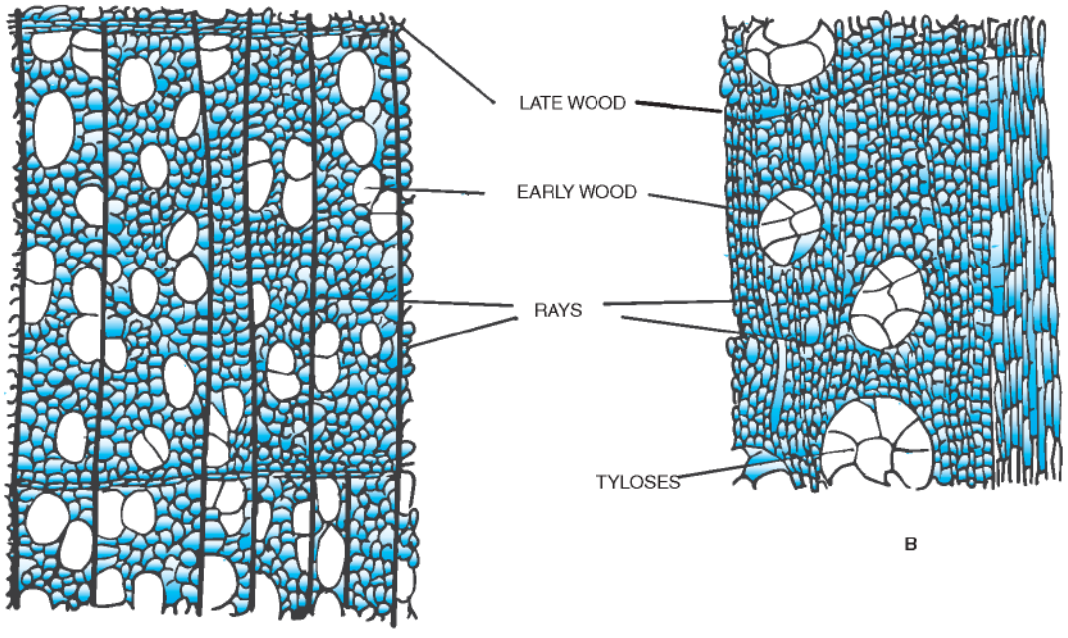


Fig. 28. Secondary xylem. **A.** Diffuse porous and **B.** Ring porous wood.

ANATOMY OF ROOT

Root is the part of the plant axis which normally develops below the soil surface and functions as an anchoring and absorbing organ. The first root of a plant develops from radicle of the embryo and is called as tap root. The tip of root is protected by root cap. Primary tap root appears from apical meristem of root. Many branches called lateral roots, appear from the tap root. Anatomically root can be differentiated from stem. Because root tip is covered by root cap, apical meristem in root tips is said to be sub-terminal. All the three types of tissue systems as in stem are found in roots *i.e.*, dermal, vascular and ground tissue system.

The outstanding characters by which a **root differs from a stem** are as under :

1. The epidermis of root is usually single layered (uniseriate) composed of thin walled cells. The cuticle and stomata are absent. Hence the term epiblema, piliferous layer and rhizodermis has been given for epidermis of root.

2. The unicellular root hairs are present which are the prolongation of epiblema cells.

3. The cortex is comparatively more simple and homogeneous and mainly composed of parenchyma cells.

4. The endodermis which is the last layer of the cortex, is prominent with characteristic casparian thickenings and is of universal occurrence.

5. The vascular bundles are radial *i.e.* xylem and phloem occur as alternate separate patches on different radii. Xylem is always **exarch** *i.e.* proto-xylem is towards the periphery. The number of rays is equivalent to the number of xylem bundles and accordingly the xylem condition in the root may be called as **monarch** (only found in some pteridophyte roots), **diarch, triarch, tetrarch, pentarch, hexarch** and **polyarch** (Fig. 29).

6. A root branch develops endogenously from the pericycle as opposed to exogenous origin of a stem branch from the growing point *i.e.* from epidermis and outer cortex layers.

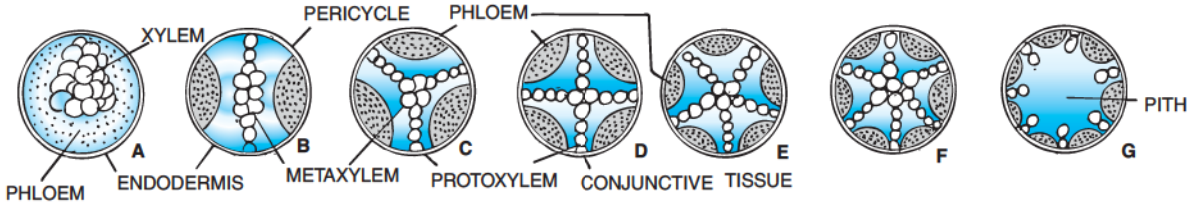


Fig. 29. A. Monarch; **B.** Diarch; **C.** Triarch; **D.** Tetrarch; **E.** Pentarch; **F.** Hexarch; **G.** Polyarch.

HISTOLOGY OF YOUNG DICOT ROOT (PEA)

1. Epiblema. It is the outermost layer made up of thin walled parenchymatous cells. It bears many unicellular root hairs (Fig. 30).

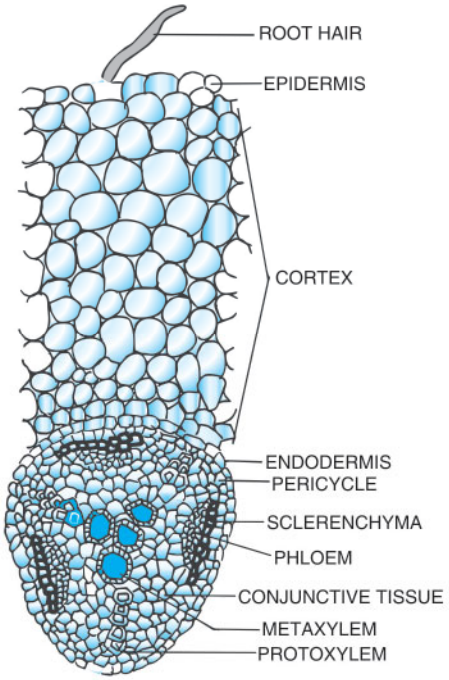


Fig. 30. T.S. Primary dicot root.

2. Cortex. Inner to epiblema, multilayered parenchymatous cortex is present.

3. Endodermis. Cortex is limited on the inner side by single layered endodermis. The endodermal cells consist of **casparian strips.**

4. Pericycle. Endodermis is followed by single layered parenchymatous pericycle.

5. Vascular bundles. The vasculature is radial *i.e.* xylem bundles alternate with phloem bundles. Usually vascular bundles are 2-6 in number. Xylem is **exarch.** Usually metaxylem bundles are seen in the centre and hence xylem varies from diarch to hexarch.

6. Pith. Pith is either absent or is very small and centrally placed.

HISTOLOGY OF MONOCOT ROOT (MAIZE)

1. Epiblema or Piliferous layer. It is the outermost layer which consists of thin walled cells. Some cells produce root hairs (Fig. 31).

2. Cortex. Inner to epiblema is a multilayered cortex consisting of compactly arranged cells.

3. Endodermis. It is single layered and lies inner to cortex. The cells are barrel shape with casparian strips on their radial walls. Opposite to protoxylem endodermal cells are thin walled and are called as **passage cells**.

ADDITIONAL USEFUL INFORMATIONS ABOUT ANATOMY OF ROOT FOR COMPETITIVE EXAMINATIONS

- *Trichoblasts are root forming cells.*
- *Aerial roots of* ***Tinospora*** *are chlorenchymatous.*
- *Lateral roots arise endogenously from pericycle.*
- *Cuticle and stomata are absent on root.*
- *Unthickened cells on endodermis are called* ***passage cells.***
- ***Polyderm*** *is a protective tissue found in roots of some plants (Rosaceae and Myrtaceae) having alternate layers of endodermal and parenchyma cells.*
- *Epiblema of root is equal to epidermis of stem, however devoid of stomata and cuticle.*
- *The cells which produce root hairs are called root hair cells or* ***trichoblasts.***
- *Because of presence of root hairs, epiblema is also called* ***piliferous layer.*** *Another name for epiblema is* ***rhizodermis.***

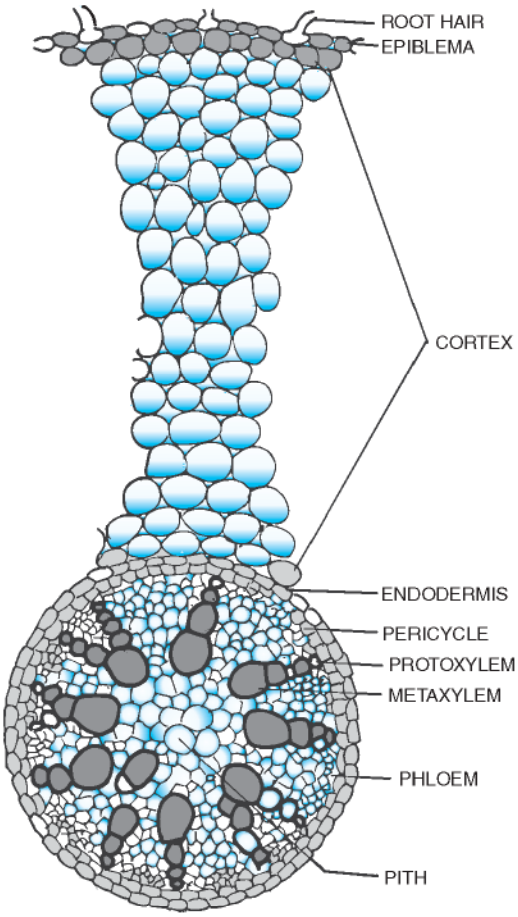


Fig. 31. T.S. monocot root.

4. Pericycle. Single layered pericycle is present inner to endodermis.

5. Vascular strand. It consists of several (8 or more) alternate radial xylem and phloem bundles. The vascular bundles are arranged in the form of ring with a pith in the center. Xylem is exarch with protoxylem towards outside and metaxylem towards centre. Xylem provides mechanical strength and is meant for conduction of water and minerals. Phloem alternates with xylem. The two are separated by conjunctive parenchyma.

6. Pith. Large pith is present in the centre, consisting of parenchymatous cells.

ANATOMY OF LEAF

Normally when we talk of a leaf, we mean a foliage leaf which is characterised by green colour, thinness and flatness. The foliage leaves are lateral appendages of a stem with limited growth. They are very important vegetative organs and chiefly concerned with the physiological process like photosynthesis and transpiration.

On the basis of mesophyll the foliage are two types :

(i) Dorsiventral Leaf. In this the mesophyll tissues are differentiated into palisade parenchyma and spongy parenchyma. It is very common in the dicotyledonous plants.

(ii) Isobilateral Leaf. Mesophyll tissue is not differentiated and having same type of cells on both adaxial and abaxial surfaces. These are commonly found in monocotyledons.

(I) HISTOLOGY OF DICOT (DORSIVENTRAL) LEAF (FIG. 32)

1. Upper epidermis. It is a single layer composed of a row of compactly arranged parenchyma cells which are cutinised and possesses a thick cuticle on the outer surface of upper (adaxial) epidermis. Stomata are generally absent.

2. Mesophyll. In between upper and lower epidermis there is chloroplast containing photosynthetic tissue called as **mesophyll.** Mesophyll is divided into two parts :

(a) Palisade parenchyma.

(b) Spongy parenchyma.

(a) Palisade Parenchyma. It is present below upper epidermis and consists of closely packed elongated cells. The cells contain abundant chloroplasts.

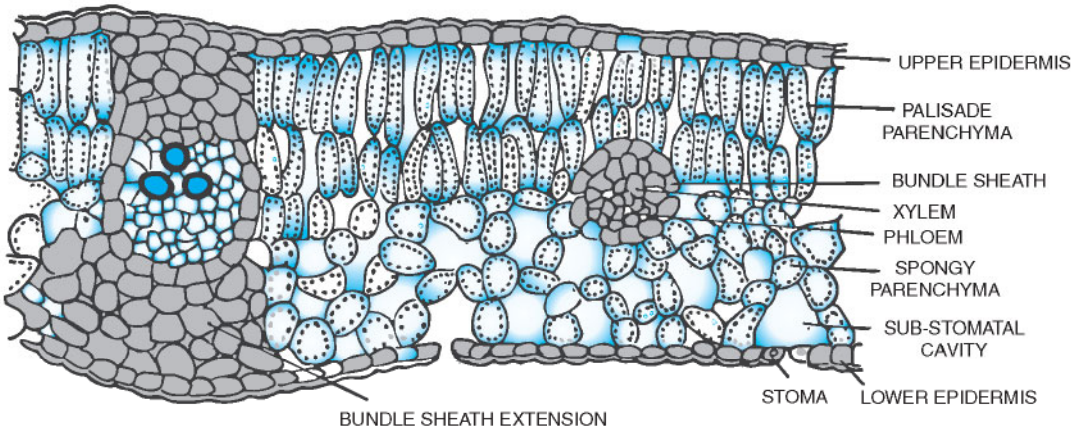


Fig. 32. V.S. of a dorsiventral mesophytic leaf (Dicot).

(b) Spongy Parenchyma. It is present below palisade tissue and consists of loosely arranged irregularly shaped cells with large intercellular spaces in between them. Spongy parenchyma is in contact with atmosphere through stomata.

3. Vascular system. There are many vascular bundles. Each vascular bundle is surrounded by a thin layer of parenchymatous cells called as bundle sheath. Each vascular bundle has xylem towards upper epidermis and phloem towards lower epidermis. Xylem is meant for conduction of water and minerals while phloem is meant for conduction of food. Cambium is absent in leaf, so there is no secondary growth in the leaf.

Each vascular bundle is **conjoint** and **collateral** *i.e.* consists of xylem and phloem which lie on same radius. The xylem is made up of tracheary elements (vessels and tracheids), xylem parenchyma and few xylem fibres. The phloem consists of sieve tubes, companion cells and phloem parenchyma. The phloem fibres are absent. Each vascular bundle is surrounded by **bundle sheath** which is made up of closely packed parenchymatous cells. **Bundle sheath extensions** may be present on both the sides of vascular bundles which are made up of parenchyma or collenchyma cells.

(II) HISTOLOGY OF MONOCOT LEAF (MAIZE) OR ISOBILATERAL LEAF

1. Upper Epidermis. It is uniseriate layer of compactly placed cells with cuticularised outer walls. The cells do not contain chloroplasts. The upper epidermis may be easily identified due to the presence of large, thin walled and empty **bulliform** cells or motor cells containing water. These cells are mainly concerned with the unrolling of the leaf during its development. Stomata are also present in this layer. In a surface view the guard cells of stomata are dumb-bell shaped and associated with subsidiary cells (Fig. 33).

2. Mesophyll. The mesophyll is not differentiated into palisade and spongy parenchyma, but is composed of rather compactly arranged isodiametric cells. The mesophyll cells contain abundant chloroplasts. They carry out photosynthesis in them.

3. Vascular Bundles. The vascular bundles are **conjoint** and **closed**. Vascular bundles are mostly small, but fairly large bundles also occur at regular intervals. The bundles of all sizes are arranged in a row. All bundles having xylem towards upper side and phloem on the lower side are encircled by a bundle sheath. This bundle sheath contains chloroplasts arranged in a centrifugal manner.

A large vascular bundle appears like that of stem bundle. The sclerenchymatous patches are found at both ends of large vascular bundle, extending upto the upper and lower epidermal layers. They provide mechanical strength.

Bundle sheath is called **panicoid** when it is single layered and **festucoid** when it is double layered.

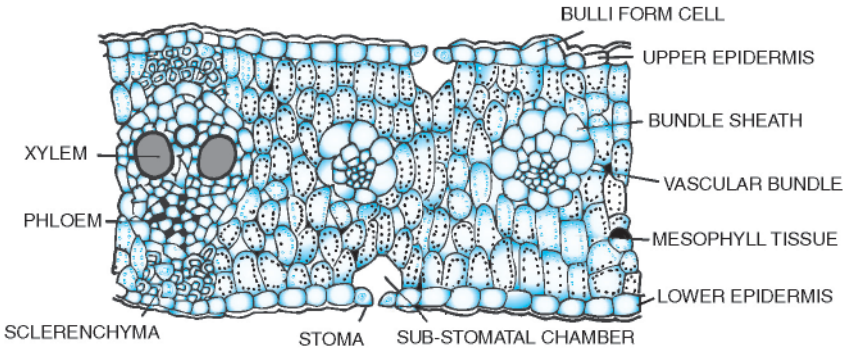


Fig. 33. V.S. monocot (isobilateral) leaf of maize.

4. Lower Epidermis. Like the upper epidermis, the lower epidermis is single layered and is composed of compactly arranged parenchyma cells having a large number of stomata as compared to the upper epidermis.

SECONDARY GROWTH IN DICOT ROOT

Secondary growth occurs in dicot root due to secondary tissues derived from the activity of cambium. In general, as in stem, there are two principal types of secondary tissues developed in the roots of dicotyledonous plants and gymnosperms *i.e.* secondary tissues in vascular cylinder and the periderm.

Secondary tissues in vascular cylinder

Secondary growth in dicot roots in vascular region takes place due to the activity of vascular cambium.

Formation of vascular cylinder. The cells of conjunctive tissue lying just below the phloem and in between the xylem turn meristematic and differentiate into vascular cambium. The pericycle cells lying outer to protoxylem also become active and meristematic and give rise to strip of cambium. Thus a continuous and wavy band of vascular cambium is formed (Fig. 34).

Formation of secondary xylem and secondary phloem. Cambium starts cutting cells, both externally as well as internally. The cells formed on the inner side of vascular cambium develop into secondary xylem and cells cut off on the outer side of cambium constitute secondary phloem (Fig. 34). In the beginning more cells are given off towards the inner side, finally developing into **secondary xylem**. As a result wavy cambium band changes itself into circular ring of cambium. Secondary xylem is made up of vessels, tracheids, xylem parenchyma and xylem fibres. The secondary xylem

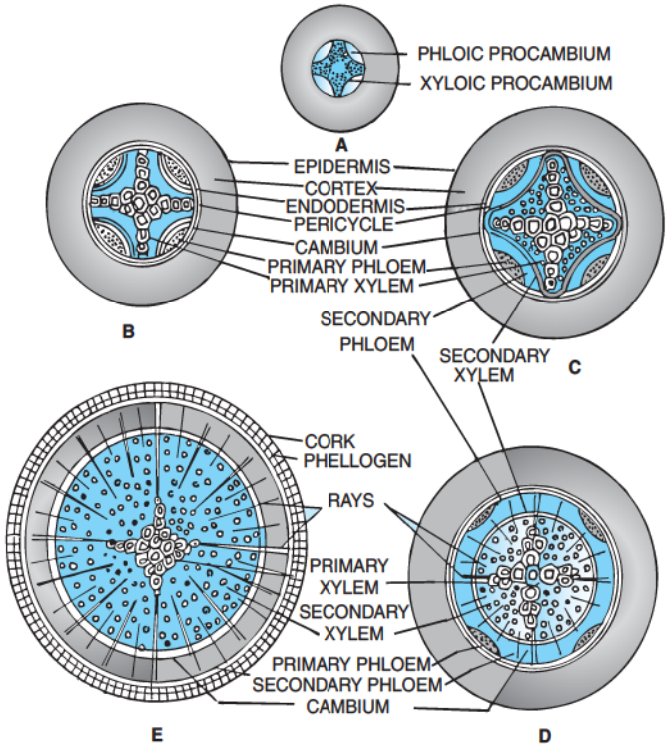


Fig. 34. Various stages during the development of secondary growth in a dicot root.

ADDITIONAL USEFUL INFORMATIONS ABOUT ANATOMY OF LEAF FOR COMPETITIVE EXAMINATIONS

- *Leaf consists of only primary tissues. Secondary growth is limited to wound healing.*
- *Leaf primordium develops from a lateral protrusion or leaf buttress. It grows initially an apical meristem (permanent in ferns) and then by intercalary meristem.*
- *The epidermis which covers the upper side of leaf is called* ***adaxial epidermis.***
- *The epidermis which covers the lower surface is called* ***abaxial epidermis.***
- *A single bundle sheath occurs in* ***panicoid*** *grasses and double sheath occurs in* ***festucoid*** *grasses.*
- *In maize and number of other grasses, mesophyll forms concentric layers around the vascular bundles that possess large sized centrifugally arranged chloroplasts in bundle sheath cells. This arrangement is known as* ***Kranz anatomy*** *which is an adaptation for tropical plants.*
- ***Unifacial*** *leaves are cylindrical in outline so that a distinction of upper or lower surface is absent e.g. Allium.*

can be easily distinguished from primary xylem by the fact that the former has a comparatively larger size of vessels and thinner walls.

Cambium gives off **secondary phloem** towards outer side. Secondary phloem comprises sieve elements, companion cells, phloem parenchyma and phloem fibres. All the tissues external to phloem are forced outwards by this development. The primary phloem is usually crushed. At this stage basic primary radial arrangement of xylem and phloem in young dicot root gets destroyed.

Ray initials of vascular cambium give rise to **vascular rays**. The rays are made up of two parts — xylem ray and phloem ray. Vascular rays help in radial conduction. Vascular rays formed opposite the protoxylem are very prominent and multiseriate.

Secondary ground tissues or periderm

Cork cambium or **phellogen** is formed from pericycle either directly or after a few divisions. Thus cork cambium in root is secondary in origin. The meristematic cells of phellogen divide tangentially and produce **secondary cortex** or phelloderm on inner side and **cork** or phellem on outside. Phellem or cork soon becomes dead, their cavities get filled up with tannin and walls become suberised. Here and there, phellem bears lenticels for gaseous exchange.

Monocotyledonous plants lacking a cambium, have no secondary growth of the type discussed above. Most of increase in diameter of roots of monocotyledonous plants occurs by the enlargement of primary tissues.

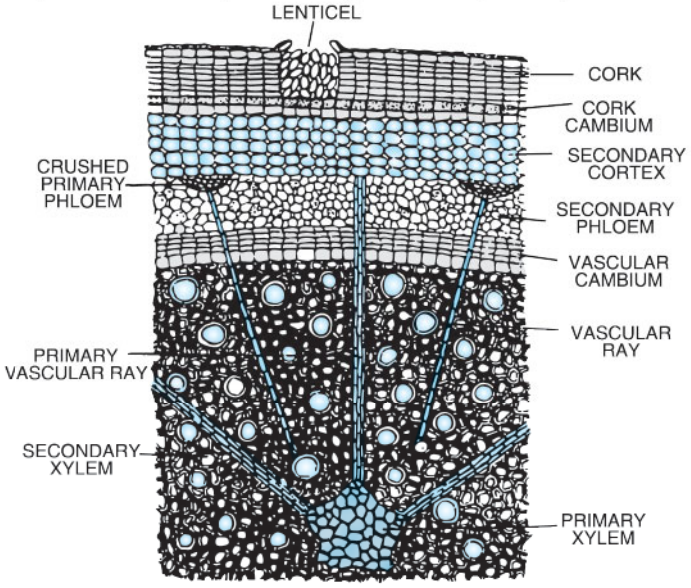


Fig. 35. T.S. Dicot (old) root— a sector showing details.

Table 13. Differences between Vegetative and Reproductive shoot apices.

Characters	Vegetative shoot apex	Reproductive shoot apex
1. Origin	Leaf primordia and axillary buds appear from it.	It gives rise to primordia of sepals, petals, stamens and pistil.
2. Shape	It is conical or dome shaped.	It is flattened or wide in shape.
3. Division	The cells of summit region divide slowly.	The cells in summit region divide rapidly.
4. Meristem	The meristem remaining active at the time of formation of shoot.	The meristem is consumed at the time of formation of flower.
5. Appendages	It forms shoot with normal foliage.	It forms flower with floral leaves like sepals, petals, stamens and carpels.
6. Growth	It is indeterminate in growth.	It is determinate in growth.

Table 14. Differences between T.S. dicot stem and T.S. monocot stem.

Characters	T.S. dicot stem	T.S. monocot stem
1. Differentiation	Ground tissue is differentiated into **cortex, endodermis, pericycle** and **pith.**	Ground tissue is a mass of **similar** cells.
2. Arrangement of vascular bundles	Vascular bundles are arranged in the form of a ring.	Vascular bundles are scattered in the ground tissue.
3. Number	The vascular bundles are a few in number.	Vascular bundles are numerous.
4. Bundle sheath	Bundle sheath is absent.	Bundle sheath is present.
5. Open or closed	Vascular bundles are open (with cambium).	Vascular bundles are closed (without cambium).
6. Secondary growth	Dicot stem shows secondary growth.	Secondary growth is absent in monocot stem.
7. Medullary rays	Medullary rays are present.	Medullary rays are absent.
8. Lysigenous cavity	Lysigenous cavity is absent in xylem.	Lysigenous cavity is present in xylem.

Table 15. Comparison between Soft wood and Hard wood.

Characters	Soft wood	Hard wood
1. Vessels	The wood lacks vessels. Also called as **non-porous wood.**	The wood contains vessels. Also called as **porous wood.**
2. Presence	It is found in gymnosperms.	It is found in dicots.
3. Tracheids	Tracheids are 90-95% in quantity.	Tracheids are only upto 5% in quantity.
4. Wood fibres	Wood fibres are fewer.	Wood fibres are abundant.

Table 16. Comparison between Spring wood and Autumn wood.

Characters	Spring wood (Early wood)	Autumn wood (Late wood)
1. Time of formation	It is produced during the favourable period of the year.	It is formed towards the close of active growing period of the year just before the arrival of unfavourable period.
2. Major constituent	Spring wood constitutes the major part of the annual ring.	Autumn wood forms a narrow strip.
3. Size of elements	It contains larger and wider elements.	Autumn wood is formed of smaller and narrower elements.
4. Number of fibres	Fibres are less in number.	Fibres are abundant in late wood.
5. Colour	The wood is lighter in colour.	The wood is darker in colour.
6. Thickening	The tracheary elements are comparatively less thickened.	The tracheary elements are comparatively more thickened.

Table 17. Comparison between Sapwood and Heartwood.

Characters	Sapwood (Alburnum)	Heartwood (Duramen)
1. Position	It is outer wood of an old stem.	It is the central wood of an old stem.
2. Colour	It is light coloured.	Heartwood is dark coloured.
3. Living cells	Living cells are present.	Living cells are lacking.
4. Functional part	Sapwood is the functional part of the secondary xylem.	Heartwood is the non-functional part of secondary xylem.
5. Tyloses	The tracheary elements are not plugged by tyloses.	The tracheary elements are plugged by tyloses.
6. Deposition	Tracheary elements do not contain any deposition in their lumen.	Tracheary elements contain deposition of tannins, resins, gums, etc.
7. Density	Sapwood of alburnum is lighter.	Heartwood of duramen is heavier.
8. Durability	It is less durable because it is susceptible to attack by pathogens and insects.	It is more durable due to its little susceptibility to the attack of pathogens and insects.

Table 18. Anatomical differences between Dicot root and Monocot root.

Characters	Dicot root	Monocot root
1. Pericycle	Pericycle produces lateral roots, cork cambium and part of vascular cambium.	Pericycle gives only lateral roots.
2. Number of bundles	Number of xylem and phloem bundles is rather small. It may vary from 2-5 or some time eight.	Xylem and phloem bundles are numerous. The number may be eight or more.
3. Type of xylem vessels	Xylem vessels are angular or polygonal in transverse section.	Xylem vessels are seen oval or rounded in transverse section.
4. Conjunctive tissue	Conjunctive tissues are parenchymatous.	Conjunctive tissues are mostly sclerenchymatous but sometimes parenchymatous.
5. Pith	Pith is either very reduced or absent.	Pith is well developed.
6. Secondary growth	Secondary growth takes place in dicot roots.	There is no secondary growth in monocot roots.

Table 19. Differences between Dorsiventral (dicotyledonous) and Isobilateral (monocotyledonous) leaves.

Characters	Dorsiventral (Dicot) leaf	Isobilateral (Monocot) leaf
1. Differentiation	The mesophyll is differentiated into palisade and spongy parenchyma.	Mesophyll is not differentiated and made up of compactly arranged thin walled cells with intercellular spaces.
2. Bulliform cells	Bulliform or motor cells are absent.	Bulliform or motor cells are present.
3. Silica	Normally silica is not deposited on epidermal cells.	Silica is usually deposited on epidermal walls.
4. Guard cells	The guard cells of stomata are kidney shaped.	The guard cells of stomata are dumb-bell shaped.
5. Colour	Upper side of leaf is dark green and lower side is light green.	Both the sides of leaf are equally green.

Table 20. Differences between Open and Closed vascular bundles.

Characters	Open vascular bundle	Closed vascular bundle
1. Definition	It bears a strip of cambium in between xylem and phloem.	Cambium not present between xylem and phloem.
2. Secondary growth	Takes place due to activity of cambium.	Does not take place.
3. Type	Collateral or bicollateral	Collateral or concentric.

Wooden logs cut for use are known as **lumber.** Large sized lumber used for carpentry is called **timber**.

CORK

Cork is obtained from the trees of many plants, particularly from cork oak (*Quercus suber*) (Fig. 36). Cork develops in woody trees due to the activity of cork cambium. Cork is thus a peripheral tissue of stem which is water proof and made up of dead cells with thick walls. The cell walls in cork, deposit waxy suberin. They are impervious to water and enclose air in water tight conditions. Commercial cork can be obtained from cork oak tree as sheets every few years. Cork is removed in the form of continuous strip of thickness of 1 inch.

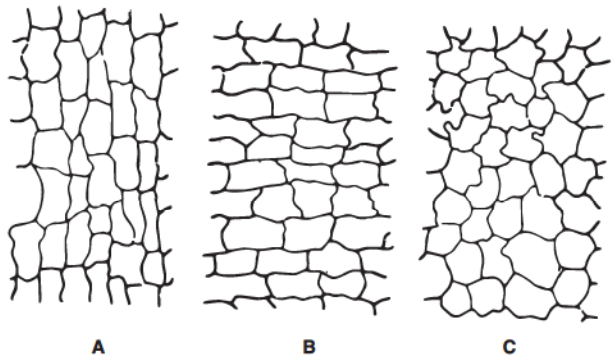


Fig. 36. Phellem **A, B, C.** Commerical cork from *Quercus suber*, transverse, radial and tangential sections respectively.

The tree grows in Mediterranean region, which is its native place. Other cork oak growing countries are Spain, Portugal, France, Italy, Tunisia and Morocco. *Quercus* tree is 20-60 fit. in height. It has a diameter of 4 ft. It is able to tolerate dry conditions due to the presence of cork. In cork oak phellogen first arises in the epidermis, forming externally masses of cork tissue and relatively few phelloderm cells. When the tree is about 20 years old, outer layer called virgin cork is removed by stripping. Now a new phellogen is formed deeper in the cortex. After 9-10 years when new cork has gained sufficient thickness, it is removed. This cork is of better quality than nearly useless virgin cork. Cork helps the tree in insulating from freezing temperatures of cold winter. It is also responsible for conservation of water in trees. Lenticels in the form of scars are present in cork for gaseous exchange.

The properties which make commercial cork valuable are its imperviousness, lightness, toughness and elasticity. Cork is highly compressible and does not catch fire easily. Being non-reactive and undamaged by liquids, it is widely used as a stopper for bottles particularly for corking wine bottles and casks. Recently cork is being utilised for the manufacturing of insulation boards, shock absorbers, linoleum, sports goods etc. Before the usage of commercial cork, cork is first of all dried in open, steamed or boiled to remove sap and tannins. This processing also helps in increasing the volume and elasticity of cork. The outer rough portion of cork is removed by hand or knife and sheets are pressed to make them flat. Cork is also used for making handles for golf clubs, life jackets, mats, hats etc. Cork is also utilised for making rooms sound proof.

IMPORTANCE OF STUDYING ANATOMY

1. Study of anatomy helps in solving **taxonomic** problems. Anatomical studies help in identifying **adulterated** spices, coffee, tea, dyes (vegetable), tobacco, saffron, asfoetida (hing), plant drugs and other plant products.

2. Wood anatomy helps in differentiating the spurious and inferior material from standard woods. Thus, anatomical studies can help in tracing inferior woods as compared to certified and standard woods required for construction, furniture, ship building, vehicles etc.

3. Anatomical studies are helpful in **pharmacognosy.** Pharmacognosy is the branch of science which deals with the study of sources, characteristics and possible uses of medicinal substances in their natural or unprepared forms.

4. Forensic experts utilize the knowledge of plant anatomy to identify various plants and plant products for solving criminal cases.

Table 21. Differences between Intrafascicular and Interfascicular cambium.

Characters	Intrafascicular cambium	Interfascicular cambium
1. Type of meristem	Primary meristem	Secondary meristem.
2. Location	In the form of strip between primary phloem and primary xylem.	It develops outside the vascular bundle.
3. Presence	Permanently present in vascular bundle.	Appears only at the time of secondary growth and formed from the cells of primary medullary rays in between two vascular bundles.
4. Origin	It is produced from procambium of apical shoot meristem.	It appears by dedifferentiation in parenchymatous cells, secondarily.

PRACTICE PROBLEMS – ANATOMY OF ROOT, STEM AND LEAF

1. What is the structure of stomata?
2. Differentiate between protoxylem and metaxylem.
3. What are annual rings?
4. What is meant by secondary growth? Which meristems are responsible for the secondary growth?
5. Differentiate between stem hair and root hair.
6. Describe the vascular bundle of a monocot root.
7. Compare T.S. of monocot and dicot stem with the help of well labelled diagrams only.
8. Compare T.S. of monocot and dicot root with the help of well labelled diagrams only.
9. Compare V.S. of dicot and monocot leaf with the help of well labelled diagrams only.

ANSWERS TO PRACTICE PROBLEMS

1. **Stomata.** The stomata are small apertures present in the epidermis of the leaf. Each stoma is bounded by two **guard cells.** In dicots two guard cells are kidney shaped while in monocots the guard cells are dumb bell shaped. The inner wall of guard cells bordering the aperture are thicker than the outer wall. In each guard cell there are present **chloroplasts.**

2.

Protoxylem	Metaxylem
1. It is the first formed xylem.	It is later formed xylem.
2. It develops before the plant organ has completed its growth.	If differentiates when the plant organ has completed its growth.
3. Protoxylem is comparatively less prominent.	Metaxylem is quite prominent.
4. It is made up of smallest and narrower elements.	Metaxylem is formed of broader and larger elements.
5. The wall thickening of the conducting elements are of simple and primitive type.	The wall thickening are of complex and advanced type reticulate scalariform or pitted.
6. Lignification occurs in the protoxylem elements before the completion of elongation of the plant part.	Lignification occurs after the completion of the elongation in the plant part.

3. **Annual rings.** The activity of the cambium varies due to the seasonal changes. During favourable conditions *i.e.* spring the cambium produces the secondary xylem (wood) and is called the spring wood. In the autumn the activity of cambium is less and produces wood of smaller diameter and is called autumn wood. These layers form the rings of secondary xylem. These are the growth rings. The growth rings of spring wood and autumn wood constitute the annual ring.
4. **Secondary growth.** The formation of secondary tissues from the lateral meristem is called **secondary growth.** It increases the diameter of stem. Secondary tissue is formed from two types of lateral meristems.

   Meristems responible for secondary growth

   1. **Vascular cambium** is present between primary xylem and primary phloem and this is called the fascicular cambium. In the medullary region interfascicular cambium is formed between two vascular bundles. Interfascicular and fascicular cambia form the complete ring in the stem. Cambium cells divide to form secondary xylem and secondary phloem.
   2. **Cork cambium or phellogen.** Cork cambium or phellogen develops in the cortex. This cork cambium produces the cork (phellem) tissue towards the epidermis and produces the phelloderm on the inner side. Cork cambium (phellogen), cork (phellem) and phelloderm constitute the periderm which is protective in nature.

5.

Stem hair	Root hair
1. They are generally multicellular.	1. Root hair are unicellular.
2. Stem hair are additional cells. They do not arise as outgrowths of the epidermal cells.	2. Root hair are tubular outgrowths of epiblema cells.
3. They may be branched or unbranched.	3. Root hair are always unbranched.
4. They are spread all over the stem.	4. They are found in clusters in young roots near the tips. It is known as root hair zone.
5. The stem hair are heavily cutinised.	5. The root-hair are not cutinised.
6. They are long-lived.	6. They are short-lived.

6. **Vascular bundle of monocot root.** It consists of several (8 or more) alternate radial xylem and phloem bundles. The vascular bundles are arranged in the form of ring with a pith in the centre.

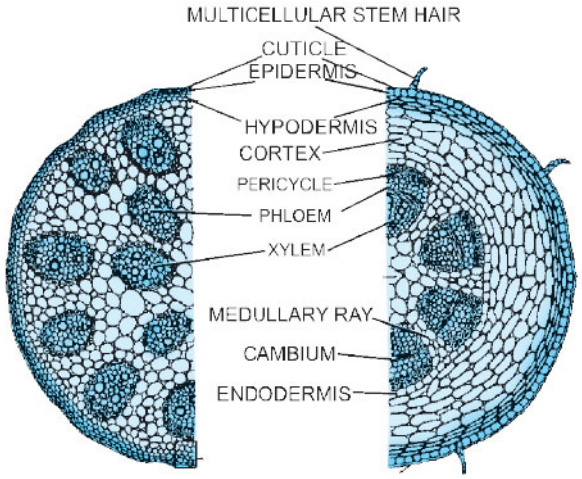
   Xylem is **exarch** with protoxylem towards outside and metaxylem towards centre.

   Function. Xylem provides mechanical strength and is meant for conduction of water and mineral.

   Phloem alternates with xylem. These two are separated by conjunctive parenchyma.

   Function. Phloem is meant for translocation of organic food.

7.



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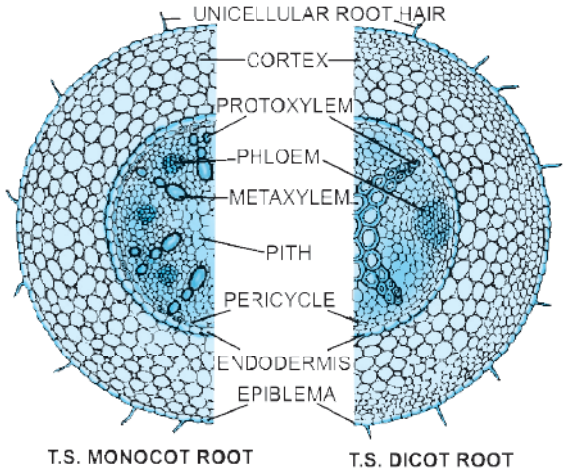

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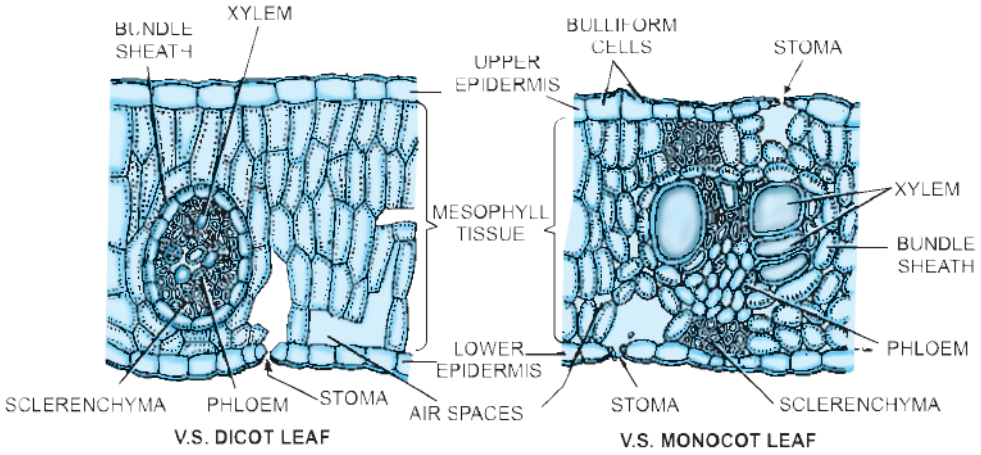


REMEMBER

- **Primary growth** is the first form of growth to take place. Whole plant can be built up by primary growth.
- In most of monocotyledonous plants and herbaceous dicotyledonous plants, it is the only type of growth.
- Primary growth is mainly due to apical and sometimes intercalary meristem.
- It is initiated due to division of meristematic cells in root apex and shoot apex meristems.
- All tissues of stem and leaves appear from apical meristem.
- **Secondary growth** is the growth in thickness due to the formation of secondary tissues by lateral meristem.

CHAPTER SUMMARY

- A **tissue** is a group of cells having a common origin and usually perform common function.
- The meristems which occur at the tips of roots and shoots produce primary tissues called **opical meristems.**
- The meristem that occurs in mature regions of roots and shoots is called **secondary** or **lateral meristem.**
- Permanent tissues having all cells similar in structure and function are called **simple tissues.** Permanent tissues having many different types of cells are called **complex tissues.**
- Xylem and phloem constitute the complex tissues in plants.
- The **epidermal tissue system** forms the outermost covering of the whole plant body and comprises epidermal cells, stomata and epidermal appendages-the trichomes and hairs.
- All tissues except epidermis and vascular bundles constitute the **ground tissue**.
- All tissues on the innerside of endodermis such as pericycle, vascular bundles and pith constitute the **stele.**
- The tissues involved in secondary growth are two lateral meristems : **vascular cambium** and **cork cambium.**
- The **spring wood** is lighter in colour and has a lower density, whereas **autumn wood** is darker and has a higher density.
- **Bark** is a non-technical term that refers to all tissues exterior to the vascular cambium.
- **Lenticels** permit the exchange of gases between the outer atmosphere and the internal tissue of stem.

KEY TERMS

Autumn wood	:	Secondary xylem formed during winter, which contains vessels and tracheids of narrow lumen.
Alburnum (sap wood)	:	It is light coloured outer region of secondary wood performing the function of conduction of sap.
Cortex	:	It is the ground tissue formed of parenchymatous cells which lies between epidermis and endodermis.
Closed vascular bundle	:	A conjoint vascular bundle in which no cambium is present between phloem and xylem.
Duramen (heart wood)	:	It is hard and dark coloured central region of secondary wood, which is unable to conduct the sap.
Endarch	:	A condition of xylem in which protoxylem lies towards the centre.
Exarch	:	A condition of xylem in which protoxylem lies towards the periphery.
Hydrophytes	:	The plants that grow in aquatic habitats.
Inter-fascicular cambium	:	A strip of cambium formed in between two intra-fascicular cambia from the cells of medullary ray.
Intra-fascicular cambium	:	It is a strip of cambium present in between primary phloem and primary xylem of the vascular bundle of a young dicot stem.
Lenticels	:	These are the aerating pores present on the surface of woody stems.
Mesarch	:	A condition of xylem in which protoxylem lies in the middle of the metaxylem.
Medullary rays	:	These are the strips of parenchyma present between vascular bundles of dicot stem.
Meristem	:	A group of similar and immature cells which are capable of dividing and forming new cells.
Metaxylem	:	It is the later formed xylem in the primary xylem, which consists of large tracheids and vessels.
Open vascular bundle	:	A conjoint vascular bundle in which a strip of cambium is present between xylem and phloem.
Primary xylem	:	The xylem that is derived from procambium.
Protoxylem	:	It is the first formed xylem element in the primary xylem, which has small tracheids and vessels.
Passage cells	:	These are thin walled cells of endodermis which permit the free passage of water.
Protoderm	:	The tissue which develops from the tunica initials of apical meristem and gives rise to epidermis.
Procambium	:	The layer of primary meristem that gives rise to vascular tissue.
Permanent tissue	:	The tissue which is composed of mature cells that have attained a definite shape and function.

Quiescent centre	:	A group of cells in the centre of the apical meristem of the root, in which mitotic division is very slow.
Stele	:	It is the central core of vascular tissue in plants surrounded by pericycle and delimited by endodermis.
Spring wood	:	It is the secondary xylem formed in spring and consists of tracheids and vessels of wider lumen.
Tyloses	:	These are balloon like ingrowths formed in the tracheids and vessels of heart wood from adjacent parenchyma cells.
Tissue	:	A group of similar or dissimilar cells, which have a common origin and perform a common function.

NCERT FILE Solved

NCERT Exercise Questions

1. State the location and function of different types of meristems.

Ans. Refer Chapter-6 under heading '**Meristematic tissue**', pages 1.

2. Cork cambium forms tissues that form the cork. Do you agree with this statement?

Ans. Refer 'Activity of cork cambium', Chapter-6. Cork cambium (phellogen) forms cork (phellem). It also forms secondary cortex (phelloderm) which is not a part of cork.

3. Explain the process of secondary growth in a stem of woody angiosperm with the help of schematic diagram. What is its significance?

Ans. Refer '**Secondary thickening in dicot stem**', Chapter-6, pages 18-22.

4. Draw illustrations to bring out the anatomical difference between :

(a) Monocot root and dicot root

(b) Monocot stem and dicot stem.

Ans. **(a)** Refer Fig. 30 and Fig. 31, pages 23-24.

(b) Refer Fig. 18 and Fig. 19, pages 15 and 17.

5. Cut a transverse section of young stem of a plant of your school garden and observe it under the microscope. How would you ascertain whether it is monocot stem or a dicot stem. Give reasons.

Ans. Take a young stem of plant available in your school garden. Cut T.S. of young stem. Place it on the slide. Find out, whether it is monocot or dicot stem on the basis of Table 14 (**Differences between T.S. dicot stem and T.S. monocot stem**), page 27.

6. The transverse section of a plant material shows the following anatomical characters :

(a) Vascular bundles are conjoint, scattered and surrounded by a sclerenchymatous bundle sheath.

(b) Phloem parenchyma is absent.

What will you identify it as?

Ans. The plant material is of monocot stem.

7. Why are xylem and phloem called complex tissues?

Ans. Both xylem and phloem are made up of more than one type of cells to perform one common major function, hence are called as complex tissue. Xylem is responsible for conduction of water and dissolved mineral salts and phloem mainly carried food. Both xylem and phloem are an assemblage of living and dead cells and may be primary or secondary in origin.

Xylem is made up of four types of cells *i.e.* **(i)** Tracheids **(ii)** Tracheae or vessels **(iii)** Xylem fibres **(iv)** Xylem parenchyma

Phloem is formed of : **(i)** Sieve tubes **(ii)** Sieve cells **(iii)** Companion cells **(iv)** Phloem parenchyma and **(v)** Phloem fibres.

8. What is stomatal apparatus? Explain the structure of stomata with labelled diagrams.

Ans. The stomatal aperture, guard cells and the surrounding subsidiary cells are together called **stomatal apparatus.** For structure of stomata refer '**stomata**' under heading "**The tissue system**", page 14.

9. Name the three basic tissue systems in the flowering plants. Give the tissue names under each system.

Ans. Refer page 14.

10. How is study of plant anatomy useful to us?

Ans. Refer '**Importance of studying anatomy**' of Chapter-6, page 29.

11. What is periderm? How does periderm formation take place in dicot stems?

Ans. Refer '**Activity of cork cambium**' of Chapter-6 pages 20-21.

12. Describe the internal structure of a dorsiventral leaf with the help of labelled diagrams.

Ans. Refer '**Histology of dicot**' **(Dorsiventral) leaf** of Chapter-6 pages 24-25.

NCERT Exemplar Problems

A. MULTIPLE CHOICE QUESTIONS

1. **A transverse section of stem is stained first with safranin and then with fast green following the usual schedule of double staining for the preparation of a permanent slide. What would be the colour of the stained xylem and phloem?**
   (a) Red and green (b) Green and red
   (c) Orange and yellow (d) Purple and orange

2. **Match the following and choose the correct option from below :**

A.	Meristem	i.	Photosynthesis, storage
B.	Parenchyma	ii.	Mechanical support
C.	Collenchyma	iii.	Actively dividing cells
D.	Sclerenchyma	iv.	Stomata
E.	Epidermal tissue	v.	Sclereids

Options:
   (a) A-i, B-iii, C-v, D-ii, E-iv
   (b) A-iii, B-i, C-ii, D-v, E-iv
   (c) A-ii, B-iv, C-v, D-i, E-iii
   (d) A-v, B-iv, C-iii, D-ii, E-i

3. **Match the following and choose the correct option from below :**

A.	Cuticle	(i)	guard cells
B.	Bulliform cells	(ii)	single layer
C.	Stomata	(iii)	waxy layer
D.	Epidermis	(iv)	empty colourless cell

Options:
   (a) A-(iii), B-(iv), C-(i), D-(ii)
   (b) A-(i), B-(ii), C-(iii), D-(iv)
   (c) A-(iii), B-(ii), C-(iv), D-(i)
   (d) A-(iii), B-(ii), C-(i), D-(iv)

4. **Identify the tissue system from among the following :**
   (a) Parenchyma (b) Xylem
   (c) Epidermis (d) Phloem

5. **Cells of this tissue are living and show angular wall thickening. They also provide mechanical support. The tissue is :**
   (a) Xylem (b) Sclerenchyma
   (c) Collenchyma (d) Epidermis

6. **Epiblema of roots is equivalent to**
   (a) Pericycle (b) Endodermis
   (c) Epidermis (d) Stele

7. **A conjoint and open vascular bundle will be observed in the transverse section of :**
   (a) Monocot root (b) Monocot stem
   (c) Dicot root (d) Dicot stem

8. **Interfascicular cambium and cork cambium are formed due to :**
   (a) Cell division
   (b) Cell differentiation
   (c) Cell dedifferentiation
   (d) Redifferentiation

9. **Phellogen and Phellem respectively denote :**
   (a) Cork and cork cambium
   (b) Cork cambium and cork
   (c) Secondary cortex and cork
   (d) Cork and secondary cortex

10. **In which of the following pairs of parts of a flowering plant is epidermis absent?**
    (a) Root tip and shoot tip
    (b) Shoot bud and floral bud
    (c) Ovule and seed
    (d) Petiole and pedicel

11. **How many shoot apical meristems are likely to be present in a twig of a plant possessing, 4 branches and 26 leaves :**
    (a) 26 (b) 1
    (c) 5 (d) 30
    (e) 4

12. **A piece of wood having no vessels (trachea) must be belong to :**
    (a) Teak (b) Mango
    (c) Pine (d) Palm

13. **A plant tissue, when stained, showed the presence of hemicellulose and pectin in cell wall of its cells. The tissue represents :**
    (a) Collenchyma (b) Sclerenchyma
    (c) Xylem (d) Meristem

14. **Fibres are likely to be absent in :**
    (a) Secondary phloem (b) Secondary xylem
    (c) Primary phloem (d) Leaves

15. **When we peel the skin of a potato tuber, we remove :**
    (a) Periderm (b) Epidermis
    (c) Cuticle (d) Sapwood

16. **A vesselless piece of stem possessing prominent sieve tubes would belong to :**
    (a) *Pinus* (b) *Eucalyptus*
    (c) Grass (d) *Trochodendron*

17. **Which one of the following cell types always divides by anticlinal cell division?**
    (a) fusiform initial cells (b) root cap
    (c) protoderm (d) phellogen

18. **What is the fate of primary xylem in a dicot root showing extensive secondary growth?**
    (a) It is retained in the centre of the axis
    (b) It gets crushed
    (c) May or many not get crushed
    (d) It gets surrounded by primary phloem

ANSWERS

1. (a);	**2.** (b);	**3.** (a);	**4.** (a);	**5.** (c);	**6.** (c);	**7.** (d);	**8.** (a);	**9.** (b);	**10.** (a);
11. (c);	**12.** (c);	**13.** (a);	**14.** (d);	**15.** (a);	**16.** (d);	**17.** (d);	**18.** (a).		

B. VERY SHORT ANSWER TYPE QUESTIONS

1. Product of photosynthesis is transported from the leaves to various parts of the plants and stored in some cell before being utilised. What are the cells/ tissues that store them?

Ans. Products of photosynthesis can be stored in fruit, root, underground stem etc. It can be stored in modified epidermal cells like lithocytes which contain cystoliths. Silica cells contain silica granules. Cork cells bear solid organic substances.

2. Protoxylem is the first formed xylem. If the protoxylem lies next to phloem. What kind of arrangement of xylem would you call it?

Ans. Endarch.

3. What is the function of phloem parenchyma?

Ans. It stores food material and substances like resin, latex etc.

4. What is present on the surface of the leaves which helps the plant prevent loss of water but is absent in roots?

Ans. Cuticle

5. What is the epidermal cell modification in plants which prevents water loss?

Ans. In monocot epidermal cells form bulliform or motor cells which help in reducing loss of water.

6. What part of the plant would show the following:

(a) Radial vascular bundle **(b) Polyarch xylem**

(c) Well developed pith

Ans. **(a)** Radial vascular bundles are present in roots.

(b) Polyarch xylem is present in monocot roots.

(c) Stem has well developed pith.

7. What are the cells that make the leaves curl in plants during water stress?

Ans. Bulliform or motor cells.

8. What constitutes the cambial ring?

Ans. Open vascular bundles bear cambium and is present between xylem and phloem. It is responsible for secondary growth.

9. Give one basic functional difference between phellogen and phelloderm.

Ans. Phellogen (cork cambium) cells are meristematic and living. It cuts off secondary cortex or phelloderm towards inside to add them to cortex.

10. Arrange the following in the sequence, you would find them in a plant starting from the periphery-phellem, phellogen, phelloderm.

Ans. Phellem (cork), phellogen, phelloderm.

11. If one debarks a tree, what part of the plant is being removed?

Ans. Debarking removes phellem, phellogen, phelloderm, crushed primary cortex, secondary phloem and primary phloem.

12. The cross-section of a plant material showed the following features when viewed under the microscope:

(a) Vascular bundles were radially arranged

(b) Four xylem strands with exarch condition of protoxylem.

To which organ should it be assigned.

Ans. Young dicot root.

13. What do hard wood and soft wood stand for?

Ans. Soft wood is mainly made up of tracheids and is present in Gymnosperms. Hard wood is made up of both vessels and tracheids and present in angiosperms.

C. SHORT ANSWER TYPE QUESTIONS

1. While eating peach or pear, it is usually seen that some stone like structures get entangled in the teeth, what are these stone like structures called?

Ans. These stone like structures are called as sclerides (stone cells). They are usually isodiametric and unbranched.

2. What is the commercial source of cork? How is it formed in the plant?

Ans. It is obtained from *Quercus suber*. It provides cork tissue in the form of bottle cork. Cork cambium or phellogen cuts off cells towards outerside to form cork or phellem. In phellem cells become highly suberised and dead.

3. Below is a list of plant fibres. From which part of the plant, these are obtained:

(a) Coir **(b) Hemp**

(c) Cotton **(d) Jute**

Ans. **(a) Coir :** It is extracted from coconut seeds.

(b) Hemp : It is obtained from phloem of stem.

(c) Cotton : It is taken out from seeds.

(d) Jute : It is obtained from phloem of stem.

4. What are the characteristic differences found in the vascular tissues of gymnosperms and angiosperms?

Ans. In gymnosperms, in xylem vessels are not found. Here instead of vessels tracheids are present.

In angiosperms, vessels are present. In gymnosperms, in phloem, companion cells are absent. In angiosperms, companion cells are present.

5. Epidermal cells are often modified to perform specialised functions in plants. Name some of them and function they perform.

Ans. **(i) Silica cells:** These cells contain silica granules.

(ii) Cork cells : Such cells bear solid organic substances.

(iii) Lithocytes : They bear calcium carbonate crystals.

(iv) Bulliform cells: They are motor cells and help in rolling of leaves to reduce the transpiration in grasses.

6. The lawn grass (*Cyanodon dactylon*) needs to be moved frequently to prevent its overgrowth. Which tissue is responsible for its rapid growth?

Ans. Maristematic tissue

7. Plants require water for their survival. But when watered excessively, plants die. Discuss.

Ans. Plants die, as due to excessive water plugging of xylem occurs.

8. A transverse section of a trunk of tree shows concentric rings which are known as growth rings. How are these rings formed? What is the significance of these rings?

Ans. These concentric rings represent the annual rings which inform the age of tree. These are formed to formation of spring wood or early wood with wider cavity xylem vessels in spring season and autumn wood or late wood with narrow xylem vessels in autumn season by cambium.

9. Trunks of some of aged tree species appear to be composed of several fused trunks. Is it a physiological or anatomical abnormality. Explain in detail.

Ans. This is due to abnormal secondary growth. Here due to anomaly, during secondary growth cortical and medullary vascular bundles are formed. Such additionally formed vascular bundles give look of fused trunks.

10. What is the difference between lenticels and stomata?

Ans. Lenticels are pores present on periderm of bark for aeration. Stomata are minute pores present on epidermis of aerial parts of plant particularly on leaves. They are guarded by guard cells and stomata perform stomatal transpiration and gaseous exchange.

11. Write the precise function of :

(a) Sieve tube (b) Interfascicular cambium

(c) Collenchyma (d) Aerenchyma

Ans. **(a) Sieve tube :** They transport organic food in plants.

(b) Interfascicular cambium: It helps in secondary growth.

(c) Collenchyma: It provides mechanical strength as well as elasticity. They can also store food.

(d) Aerenchyma: It consists of air spaces for gaseous exchange in some aquatic plants. Such plants become buoyant and can easily afloat on water.

12. The stomatal pore is guarded by two kidney shaped guard cells. Name the epidermal cells surrounding the guard cells. How does a guard cell differ from an epidermal cell? Use a diagram to illutrate your answer.

Ans. The guard cells are living, bear chloroplasts and are surrounded by subsidiary cells. They can expand or contract and have the capacity of opening and closure. They may be kidney shaped (in dicots) or dumb-bell shaped (in monocots). They are present in epidermal cells.

For diagram refer Fig. 16 of this chapter.

13. Point out the differences in the anatomy of leaf of peepal (*Ficus religiosa*) and maize (*Zea mays*). Draw the diagram and label the various parts.

Ans. Refer Fig. 32 and 33 and table 19 of this chapter.

14. Palm is a monocotyledonous plant, yet it increases in girth. Why and how?

Ans. Normally secondary growth is absent in monocot plants due to absence of cambium. In palm, secondary growth occurs due to primary thickening meristem. It originates below the region of attachment of young leaf primordia. This meristem shows periclinal division to form anticlinal rows of cells which are responsible for increasing the width of plant first and height at later stages.

D. LONG ANSWER TYPE QUESTIONS

1. The arrangement of ovules within the ovary is known as placentation. What does the term placenta refer to? Draw various types of placentations in the flower as seen in T.S. and V.S.

Ans. Refer 'Placentation' Fig. 61' of chapter 5.

2. Decidous plants shed their leaves during hot summer or in autumn. This process of shedding of leaves is called abscission. Apart from physiological changes what anatomical mechanism is involved in the abscission of leaves.

Ans. Abscission zones occur at the base of leaf petioles. Leaves are shed through number of biological actions which weaken cell walls and initiate the cells tearing away from one another.

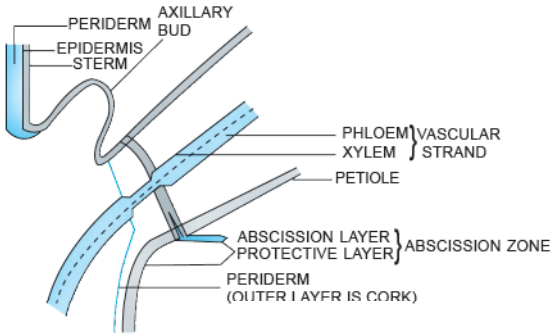
Abscission zone is composed of:

(a) A cell wall degradation area

(b) A shear force generation area

(c) A tree protection zone

Abscission zone cells secrete pectinase and cellulase. The middle lamella 'glue' which holds cell together, begins to dissolve in abscission zone.



3. Is *Pinus* an evergreen tree? Comment.

Ans. *Pinus*, needles bear xerophytic characters like:

(i) Thick bark (ii) Needles with sunken stomata.

Pinus is adapted to conditions of scanty rainfall, precipitation in the form of snow, low temperature etc. It donot shed its leaves and continues to photosynthesize.

Thus it is an evergreen tree.

4. Each of the following terms has some anatomical significance. What do these terms mean? Explain with the help of line diagrams.

(a) Plasmadesmoses (b) Middle lamella

(c) Secondary wall

Ans. Refer text.

5. Distinguish between the following:

(a) Exarch and endarch condition of protoxylem

(b) Stete and vascular bundle

(c) Protoxylem and metaxylem

(d) Interfascicular cambium and intrafascicular cambium

(e) Open and closed vascular bundles

(f) Stem hair and root hair

Ans. (a) Exarch : In this condition protoxylem lies towards metaxylem.

Endarch : In this condition protoxylem lies towards inner side of metaxylem.

(b) Stele and vascular bundle:

Vascular bundle represents the ring of xylem and phloem and vascular bundles along with endodermis and pericycle represent **stele**.

(c) Differences bewteen Protoxylem and Metaxylem: Refer text' – Practice problems – Anatomy of root, stem and leaf.

(d) Differences between interfascicular cambium and intrafascicular cambium : Refer table 21 of this chapter.

(e) Differences between open and closed vascular bundle : Refer table 20 of this chapter.

(f) Stem hair and root hair: Stem hairs are multicellular and exogenous in origin.

Root hairs are unicellular and are extension of epiblema cells.

HOTS Higher Order Thinking Skills & Brain Twisting

QUESTIONS WITH ANSWERS

Very Short Answer Questions *One mark each*

1. Name any two lateral meristems in plants.

Ans. Fasciular cambium and phellogen (cork cambium).

2. Why xylem vessels are called syncytes ?

Ans. As xylems vessels are made up from number of cells, they are called as syncytes.

3. Write about the chemical composition of collenchyma cells.

Ans. Cellulose, hemicellulose and pectin.

4. What are fibres ?

Ans. Fibres are narrow, elongated and fiber like. They are usually found in bundles. They are derived directly from meristematic cells.

5. What are sclereids ?

Ans. Sclereids are short, broad and are found individually or in small groups. They are formed by secondary thickening of parenchyma cells.

6. From which part of the plant coir and hemp are obtained ?

Ans. Coir : Mesocarp of fruit (drupe) of coconut.

Hemp : Phloem or bast fibres.

7. Why the colour of heart wood is dark ?

Ans. Due to presence of tannin, gums, oils and resins.

8. Mention the constituents of periderm.

Ans. Phellogen, phellem and phelloderm.

Short Answer Questions *Two marks each*

1. Write the functions of phellogen and phelloderm.

Ans. Phellogen : It is meristematic.

Phelloderm : It stores food material.

2. Why the root apical meristem is sub-terminal ? What is its location ?

Ans. It is due to presence of root cap. Root apical meristem is located at root tip.

3. Classify vascular bundles on the basis of postion of protoxylum.

Ans. **Exarch :** Protoxylem faces towards periphery.
Endarch : Protoxylem faces towards centre.
Mesarch : Protoxylem is present in the centre.

4. Write characteristics of shoot apex.

Ans. It is apical in nature. It bears lateral appendages in the form of leaves. It bears distinct nodes and itnernodes.

5. What is open type of vascular bundle ?

Ans. In this case, cambium is present in between xylem and phloem of vascular bundles e.g. sunflower.

6. Write any two characteristics of collenchyma.

Ans. (i) It is made up of living cells.
(ii) The cell wall is unevenly thickened.

7. Define aerenchyma.

Ans. It is made up of small parenchyma cells arranged in the form of network and bear large air cavities.

8. What is pro-meristem ?

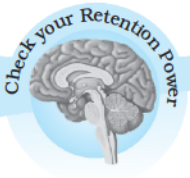
Ans. It is a part of apical meristem made up of actively dividing cells and their immediate derivatives.

Short Answer Questions *Three marks each*

1. What are the characteristics of Krenz anatomy?
2. How an annual ring is formed ?
3. Define the terms : (i) alburnum (ii) duramen.
4. What are sieve elements ? Why is the septum between two sieve tube elements called sieve plate ?
5. Distinguish between monocot root and dicot root.
6. Distinguish between monocot stem and dicot stem.
7. Classify meristem on the basis of origin.

Long Answer Questions *Five marks each*

1. Which are complex permanent tissues. Explain with the help of diagrams.
2. Describe the internal structure of a dorsiventral leaf with the help of well labelled diagram.
3. Discuss the process of secondary growth in the stems of woody angiosperms.
4. Explain the anatomy of a monocot root.
5. Differentiate between sapwood and heartwood.



QUICK MEMORY TEST

A. Say True or False

Write "True" or "False".

1. Aerenchyma is a specialised parenchyma occuring in aquatic plants.
2. Sieve cells are most commonly found in the lower vascular plants.
3. A vascular bundle laking cambium is called closed bundle.
4. In *Aristolochia* anomalous secondary growth is present
5. If a sign was nailed in the trunk of the tree six feet above the ground eight years back, the height of this sign will remain at same point, although the tree grows every year by 40cms.
6. In quiescent centre cells are active.
7. Root cap is formed from calyptrogen in monocots.
8. Intercalary meristem is present at tip of branches.
9. In stem branches arise endogenously.
10. Shoot apex changes its activity in reproductive phase.
11. Parenchyma is complex permanent tissue.
12. Sclerenchyma is a simple supportive tissue of highly thick walled cells.
13. In conjoint vascular bundles, xylem and phloem are present separately.
14. Root hair are multicellular.
15. Mesophyll in dicot leaf is differentiated into palisade and spongy parenchyma.
16. In bicollateral vascular bundles, phloem and cambium are present on one side.

17. In closed vascular bundle, cambium is present.
18. Sap wood is meant for conduction of sap.
19. Casparian strips are present in the pericycle.
20. Pith is present in monocot root.
21. Stoma is surrounded by kidney shaped guard cells in monocots.
22. Lysigenous cavity is present in monocot stem.
23. Age of a tree can be known by counting its annual rings.
24. Phellogen is primary cambium.
25. The vascular strand which goes to leaf is called leaf trace.

B. Complete the missing links

Fill in the following sentences with suitable words :

1. Protoderm gives rise to .....
2. Examples of secondary meristem are cork cambium and ..... cambium.
3. In radial vascular bundles, xylem and phloem patches occur in ..... patches.
4. Pith is large and well developed in ..... root ..... .
5. Exarch type of ..... is found in roots.
6. Intercellular spaces are present in the cells of the ..... of dicot root.
7. Pith is small or absent in ..... roots.
8. Vessels are present in ..... .
9. In ..... tracheids, thickening material is deposited in the form of rings.
10. Radial vascular bundles are found in ..... .
11. In ..... type of bundle, in between xylem and phloem intrafascicular cambium is present.
12. Xylem in roots is ..... .
13. In dicot stem vessels are ..... .
14. Vascular bundle in monocot stem is surrounded by ..... sheath.
15. Heart wood is dark ..... in colour.

C. Choose the correct alternative

1. **Sap wood/Heart wood** is dark brown in colour.
2. Pith in **dicot root/monocot root** is often absent.
3. Interfascicular cambium is a **primary/secondary** meristem.
4. Secondary growth does not occur in **monocot/dicot** stem.
5. A **tracheid/vessel** consists of row of cells placed one above the another.
6. Xylem and phloem lie together on same radius in **collateral/radical** type of vascular tissue system.
7. **Fibres/sclereids** are short, broad and occur individually or in small groups.

Answers QUICK MEMORY TEST

A. Say True or False

1. True; **2.** True **3.** True **4.** True **5.** True.**6.** False. Cells are inactive in quiescent centre. **7.** True **8.** False. Intercalary meristem is present at the nodes of grasses. **9.** False. In stem branches arise exogenously. **10.** True **11.** False Parenchyma is a simple permanent tissue. **12.** True **13.** False. In conjoint vascular bundle xylem and phloem are present on same axis. **14.** False Root hairs are always unicellular. **15.** True **16.** False. In bicollateral vascular bundles, phloem and cambium are present on both sides of stem.**17.** False. In monocot stem there is closed vascular bundle as cambium is absent. **18.** True **19.** False. Casparian strips are present in endodermis. **20.** True **21.** False. Guard cells in monocots are dumb-bell shaped. **22.** True **23.** True **24.** False. Phellogen develops from cortex so it is secondary in origin. **25.** True.

B. Complete the missing links

1. epidermis; **2.** interfascicular cambium; **3.** alternate; **4.** monocot; **5.** xylem **6.** cortex; **7.** dicot; **8.** angiosperms; **9.** annular; **10.** roots; **11.** open; **12.** exarch; **13.** polygonal; **14.** sclerenchymatous; **15.** brown.

C. Choose the correct alternative

1. Heart wood ; **2.** Dicot root ; **3.** Secondary; **4.** Monocot ; **5.** Vessel ; **6.** Collateral ; **7.** Sclereids.

REVISION EXERCISES

Very Short Answer Questions

One mark each

1. Name the cavity found in the vascular bundles of monocot stems.
2. Name the substance of which cuticle of leaf is made up of?
3. From where do the secondary meristems appear?
4. Name the tissue which acts like a sponge in hydroscopic roots.
5. In which type of stem, the vascular bundles are arranged in a ring?
6. Which types of meristems can be classified on the basis of position in the plant body?
7. Name the condition, when xylem is surrounded on all the sides by phloem.
8. Name two specialised kinds of parenchyma.
9. Name tissue represented by jute fibres in making ropes.
10. Which one out of root or stem shows endarch arrangment of xylem? What is meant by endarch arrangement?
11. Name two types of sieve elements found in phloem.
12. Name tissues which provide mechanical strength to plant organs.
13. What makes the roots apical meristem subterminal?
14. Where are companion cells located in flowering plants? What are their functions?
15. Write two functions of casparian strips in plant roots
16. What is the advantage of lignocellulose in wall of xylem?
17. What is hard wood?
18. A cross section of a plant material shows the following features under the microscope. There are many vascular bundles scattered in the parenchymatous tissue. Xylem is endarch. What kind of plant part shows the above anatomy.
19. Give two examples of fruits having sclereids.
20. What use are phloem fibres put to?
21. A cross section of a plant material shows the following features under the microscope : vascular bundles are radially arranged. These are four xylem strands showing exarch condition. What is this plant part?
22. What category of a permanent plant cell is a companion cell?
23. The cross section of a plant material shows the following anatomical features under the microscope :
    (a) Vascular bundles are radially arranged.
    (b) Four xylem strands with exarch condition of the protoxylem.
    To which organ should it be assigned?
24. The tissues involved in secondary growth of dicot plants are vascular cambium and ..... . ***(Kerala Board 2017)***

ANSWERS

1. Lysigenous cavity
2. Cutin **3.** From permanent tissues **4.** Velamen **5.** Dicot stem **6.** Apical, intercalary and lateral **7.** Mesarch.
8. Aerenchyma and chlorenchyma
9. Phloem fibres **10.** Stem. In endarch xylem, protoxylem is present towards centre (pith) and metaxylem is faced towards outerside. **11.** Sieve tubes and sieve cells **12.** Sclerenchyma and xylem
13. Presence of root cap makes the root
14. Companion cells are located in phloem cells of vascular tissue. They support the sieve tubes.
15. (a) Attachment of protoplast with suberin (casparian) strip.
16. Lignocellulose provides rigidity, thickness and resistance.
17. Angiospermic wood. **18.** Monocot stem
19. Mango and tomato **20.** Phloem fibres of plants like jute are used for making ropes.
21. Dicot root, **22.** Companion cells are specialised thin walled parenchymatous cells found to be associated with sieve tubes.
23. Dicot root.
24. Cork cambium.

Short Answer Questions — *Two marks each*

1. Based on position, classify various types of meristems.
2. Sieve tubes in angiosperms are associated with specialised parenchyma cells. Name those cells. How do they help sieve tube members?
3. Name the various component cells of xylem. Which of them does not have a nucleus?
4. How are exarch and endarch conditions different anatomically in stem and root?
5. How is it advantageous for an organism to be made of different kinds of cells instead of one kind?
6. Give any four examples of secondary meristem.
7. What are sclereids?
8. If one debarks a tree, what parts of plant are being removed?
9. From which part of the plant fibers are obtained :
   (a) Hemp (b) Cotton (c) Jute
10. Palm is a monocotyledonous plant, yet it increases in girth. How?
11. Compare the formation of vascular cambia in dicot stem and dicot root.
12. Differentiate between meristematic and permanent tissue. *(Nagaland Board 2018)*
13. Illustrate two functions of collenchyma tissue. *(Manipur Board 2018)*

ANSWERS

1. (a) Apical meristem, Intercalary meristem (b) Lateral meristem
2. Companion cells. They help in physiological working of sieve tube members.
3. Various component cells of xylem are : Tracheids, vessels, xylem parenchyma and xylem fibres. Only xylem parenchyma of above bears nucleus.
4. In stem anatomical condition is endarch in dicot as well as monocot stem. In endarch condition protoxylem lies towards the innerside of vascular bundle. However, in anatomy of root, the condition is exarch i.e. protoxylem is towards outside and metaxylem is towards centre.
5. Multicellular organisms have advantages over single celled organisms because there is division of labour. Tissues perform a definite specialized function. It also increases the efficiency of body.
6. **(i)** Cambium of dicot root; **(ii)** Cork cambium of root; **(c)** Cork cambium of stem; **(iv)** Interfascicular cambium of stem.
7. Sclereids are highly thick walled, hard and strongly lignified. They are mostly isodiametric, polyhedral, short and cylindrical. These are dead cells with very narrow cell cavities.
8. Cork, cork cambium, secondary cortex and secondary phloem.
9. **Hemp *(Cannabis)* :** Phloem or bast fibres
   Cotton : Trichomes or hair from seed surface of *Gossypium*.
   Jute *(Corchorus)* : Phloem or bast fibres.
10. Due to presence of residual mertistem or thickening meristem below leaf primordia. It adds ground parenchyma and vascular bundles.
11. **Vascular cambium in dicot stem:** In origin, it is partly primary and partly secondary. The primary component is called **intrafascicular cambium.** It is found inside the vascular bundle between the xylem and the phloem. Secondary part of vascular cambium called **interfascicular cambium**. It develops in the form of strips at the level of intrafascicular cambium. The parenchymatous cells of this region turn meristematic by dedifferentiation. This division leads to joining of the two types of cambia for formation of a complete ring of vascular cambium.
    Vascular cambium in dicot root: Part of conjunctive parenchyma or tissue below the phloem bundles dedifferentiates to form brick-shaped cells of vascular cambium. The process extends laterally between the cells of xylem and phloem bundles. Finally portion of the pericycle in contact with protoxylem becomes meristematic producing a complete continuous ring of wavy vascular cambium.
12. Refer Table 4 of this chapter.
13. (i) **Collenchyma** provides rigidity and strength to the plant body due to thickenings.
    (ii) It resists the tearing effect of wind on the leaves due to its presence along the margins of some leaves.

Short Answer Questions — *Three marks each*

1. What are sclereids?
2. Name the tissue which provides mechanical strength to the plant organs?
3. What is an annual ring?
4. The cross section of a plant material shows the following anatomical features under the microscope : (a) the vascular bundles are radially arranged (b) four xylem strands with exarch condition of the protoxylem. To which organ should it be assigned?

5. Name the tissue represented by the jute fibres used for making the ropes.
6. Indicate the location of cambium in a dicot stem.
7. Why a large number of stomata are present at the lower surface of the dicotyledonous leaves in the terrestrial plants?
8. Draw a labelled diagram showing L.S. of phloem.
9. Draw well labelled diagram showing T.S. of dicot root.
10. You are provided with unlabelled slides of transverse sections of dicot and monocot stem. Give in tabular form the list of characters, which will help you in differentiating and attaining the labels on slide
11. Describe the vascular bundle of a monocot root.
12. Differentiate between
    (a) Tracheid and vessel **(b)** Parenchyma and collenchyma **(c)** Open and closed vascular bundles
    (d) Sapwood and heart wood **(e)** Root hairs and stem hairs.

Long Answer Questions

Five marks each

1. Mention two differences in the vascular bundles of sunflower and maize stems.
2. What is collenchyma? Explain its structure and function in plant body of a herbaceous angiosperm?
3. Describe the elements of phloem and xylem with the help of suitable diagrams.
4. Describe the anatomical features of a monocotyledonous stem.
5. Describe the process of secondary growth in dicotyledonous root.
6. Describe the process of secondary growth in dicotyledonous stem.
7. Discuss the V.S. of dicot leaf.
8. Discuss the V.S. of monocot leaf.

COMPETITION FILE OBJECTIVE TYPE QUESTIONS

A. MULTIPLE CHOICE QUESTIONS (MCQs):

(From AIPMT & Other Competitive Examinations)

1. Aerenchyma is present in which of the following plants?
   (1) *Neptunia* (2) *Potamogeton* (3) *Bryophyllum* (4) *Vallisneria*
   Codes : (a) 1, 2 and 3 are correct (b) 1 and 2 are correct
   (c) 2 and 4 are correct (d) 1 and 3 are correct ***(BHU 2007)***
2. Tyloses thickenings are seen in :
   (a) Collenchyma (b) Phloem cells
   (c) Ray parenchyma only (d) Ray parenchyma and xylem cells ***(BVP 2007)***
3. In a woody dicotyledonous tree, which of the following parts will mainly consist of primary tissues?
   (a) Stem and root (b) All parts
   (c) Shoot tips and root tips (d) Flowers, fruits and leaves ***(JIPMER 2007)***
4. A meristematic region present between xylem and phloem of open vascular bundle is called :
   (a) Medullary ray (b) Pericycle (c) Pith (d) Intrafascicular cambium ***(H.P. 2007)***
5. Opening in the core tissue which permit exchange of gas between atmosphere and internal tissue is called :
   (a) Complementary tissue (b) Periderm (c) Lenticel (d) Bark ***(H.P. 2007)***
6. Alburnum is also called as :
   (a) Autumn wood (b) Heart wood (c) Sap wood (d) Spring wood ***(J and K 2007)***
7. Which of the following statements is/are true?
   (A) Uneven thickening of cell wall is characteristic of sclerenchyma
   (B) Periblem forms the cortex of the stem and the root
   (C) Tracheids are the chief water transporting elements in gymnosperms
   (D) Companion cell is devoid of nucleus at maturity
   (E) The commercial cork is obtained from *Quercus suber*

Code :

(a) A and D only (b) B and E only (c) C and D only
(d) A, B and C only (e) B, C and E only (*Kerala 2008*)

8. The waxy material deposited in the casparian strip of the endodermis is :

(a) Pectin (b) Suberin (c) Cellulose
(d) Lignin (e) Hemicellulose (*Kerala 2008*)

9. The vascular cambial ring of a dicot stem is :

(a) Primary in origin (b) Secondary in origin
(c) Embryonic in origin (d) Tertiary in origin
(e) Partly primary and partly secondary in origin (*Kerala 2008*)

10. Consider the following statements :

(A) In a dicot root, the vascular bundles are collateral and endarch
(B) The inner most layer of cortex in a dicot root is endodermis
(C) In a dicot root, the phloem masses are separated from the xylem by parenchymatous cells that are known as the conjunctive tissue

Codes : Of these statements given above :

(a) A is true; but B and C are false (b) B is true; but A and C are false
(c) A is false; but B and C are true (d) C is false; but A and C are true
(e) C is true; but A and B are false (*Kerala 2008*)

11. Which of the following is true?

(a) Vessels are unicellular and with narrow lumen (b) Vessels are multicellular and with wide lumen
(c) Tracheids are unicellular and with wide lumen (d) Tracheids are multicellular and with narrow lumen (*DUMET 2009*)

12. In annual ring, the light coloured part is known as :

(a) Early wood (b) Late wood (c) Heart wood (d) Sap wood (*DUMET 2009*)

13. Jute fibres are obtained from the :

(a) Secondary phloem (b) Pith (c) Xylem (d) Endoderms (*DUMET 2009*)

14. The annular and spirally thickened conducting elements generally develop in the protoxylem when the root or stem is :

(a) Maturing (b) Elongating (c) Widening (d) Differentiating (*CBSE 2009*)

15. In barley stem, vascular bundles are :

(a) Open and scattered (b) Closed and scattered (c) Open and in a ring (d) Closed and radial (*CBSE 2009*)

16. Anatomically fairly old dicotyledonous root is distinguished from the dicotyledonous stem by :

(a) Absence of secondary xylem (b) Absence of secondary phloem
(c) Presence of cortex (d) Position of protoxylem (*CBSE 2009*)

17. Palisade parenchyma is absent in leaves of :

(a) *Sorghum* (b) Mustard (c) Soybean (d) Gram (*CBSE 2009*)

18. Reduction in vascular tissue, mechanical tissue and cuticle is characteristic of :

(a) Xerophytes (b) Mesophytes
(c) Epiphytes (d) Hydrophytes (*CBSE 2009*)

19. In dicotyledonous roots, the initiation of lateral roots takes place in :

(a) Endodermal cells (b) Cortical cells (c) Epidermal cells
(d) Procambial cells (e) Pericycle cells (*Kerala 2011*)

20. In grasses, certain adaxial epidermal cells along the veins modify themselves into large empty, colourless cells called :

(a) Bulliform cells (b) Companion cells (c) Guard cells
(d) Subsidiary cells (e) Albuminous cells (*Kerala 2011*)

21. Function of companion cells is :

(a) Loading of sucrose into sieve elements by passive transport
(b) Loading of sucrose into sieve elements
(c) Providing energy to sieve elements for active transport
(d) Providing water to phloem (*CBSE 2011*)

22. Some vascular bundles are described as open because these :
(a) Possess conjunctive tissue between xylem and phloem
(b) Are not surrounded by pericycle
(c) Are surrounded by pericycle but not endodermis
(d) Are capable of producing secondary xylem and phloem *(CBSE 2011)*

23. As compared to a dicot root, a monocot root has:
(a) More abundant secondary xylem (b) Many xylem bundles
(c) Inconspicuous annual rings (d) Relatively thicker periderm *(AIPMT 2012)*

24. A dicot plant in which scattered vascular bundles are present in stem is:
(a) *Yucca* (b) *Peperomia* (c) *Dolichos* (d) *Helianthus* *(AFMC 2012)*

25. The long plants are capable of standing erect due to presence of:
(a) Sclerenchyma (b) Collenchyma (c) Parenchyma (d) Prosenchyma *(BHU 2012)*

26. Which of the following contributes the most to water conduction in plants?
(a) Sieve tubes (b) Xylem vessels (c) Trachea (d) Sieve cells *(BHU 2012)*

27. Radial conduction of water takes place by :
(a) Vessels (b) Vessels and trachieds
(c) Phloem (d) Ray parenchyma cells *(AMU 2012)*

28. Pear fruits are gritty due to the presence of :
(a) Tracheids (b) Vessels
(c) Fibres (d) Sclereids *(J & K 2012)*

29. Tracheids differ from other tracheary elements in :
(a) Having casparian strips (b) Being imperforate
(c) Lacking nucleus (d) Being lignified. *(AIPMT 2014)*

30. Centrifugal development of xylem occurs in :
(a) Stem (b) Root (c) Leaf (d) Flower *(M.P.PMT 2013)*

31. The term bark refers to :
(a) Primary and secondary phloem only
(b) Periderm only
(c) Primary and secondary phloem only
(d) Secondary xylem and cambium only
(e) Periderm, secondary phloem and vascular cambium only *(Kerala 2013)*

32. Epidermis is produced from :
(a) Ground meristem (b) Phellogen (c) Procambium (d) Protoderm *(Odisha 2013)*

33. A simple living permanent tissue absent in roots is :
(a) Collenchyma (b) Chlorenchyma
(c) Parenchyma (d) Aerenchyma *(Maharashtra CET 2014)*

34. What anatomical structure will you use to distinguish between old dicot stem and old dicot root ?
(a) Secondary phloem (b) Protoxylem
(c) Cortical cells (d) Secondary xylem *(CBSE 2014)*

35. Closed vascular bundles lack :
(a) Cambium (b) Pith
(c) Ground tissue (d) Conjunctive tissue *(J & K CET 2015)*

36. Read the different components from (i) to (iv) in the list given below and tell the correct order of the components with reference to their arrangement from outer side to inner side in a woody dicot stem :
(i) Secondary cortex (ii) Wood (iii) Secondary phloem (iv) Phellem
The correct order is:
(a) (iv), (i), (iii), (ii) (b) (iv), (iii), (i), (ii)
(b) (iii), (iv), (ii), (i) (d) (i), (ii), (iv), (iii) *(AIPMT 2015)*

37. Cortex is the region found between:
(a) Epidermis and stele (b) Pericycle and endodermis
(c) Endodermis and pith (d) Endodermis and vascular bundle *(NEET-II 2016)*

38. Conifers are adapted to tolerate extreme environment condition because of:
(a) Broad haedy leaves (b) Superficial stomata
(c) Thick cuticle (d) Hemicellulose *(NEET-II 2016)*

39. One of the major components of cell wall of most fungi is:
(a) Chitin (b) Peptidoglycan
(c) Cellulose (d) Presence of vessels *(NEET-I 2016)*

40. Specialised epidermal cells surrounding the guard cells are called:
(a) Complimentary cells (b) Subsidiary cells
(c) Bulliform cells (d) Lanticels *(NEET-I 2016)*

41. Which of the following is made up of dead cells?
(a) Collenchyma (b) Phellem
(c) Phloem (d) Xylem parenchyma *(NEET 2017)*

42. Secondary xylem and phloem in dicot stem are produced by:
(a) Vascular cambium (b) Phellogen
(c) Apical meristems (d) Axillary meristems

43. Plants having little or no secondary growth are:
(a) Deciduous angiosperms (b) Conifers
(c) Grasses (d) Cycads

ANSWERS

1. (c);	**2.** (d);	**3.** (c);	**4.** (d);	**5.** (c);	**6.** (c);	**7.** (e);	**8.** (b);	**9.** (e);	**10.** (c);
11. (b);	**12.** (a);	**13.** (a);	**14.** (c);	**15.** (b);	**16.** (d);	**17.** (a);	**18.** (d);	**19.** (e);	**20.** (a);
21. (b);	**22.** (d);	**23.** (b);	**24.** (b);	**25.** (a);	**26.** (b);	**27.** (d);	**28.** (d);	**29.** (b);	**30.** (a);
31. (c);	**32.** (d);	**33.** (a);	**34.** (b);	**35.** (a);	**36.** (a);	**37.** (a);	**38.** (c);	**39.** (b);	**40.** (b);
41. (b);	**42.** (a);	**43.** (c).							

B. CBSE - PMT (MAIN EXAMINATION) QUESTIONS :

1. Fill in the blanks with the suitable words out of the followings :
(Primary, Apical, Intercalary, Lateral, Pond, Tree, Xylem, Secondary, Phloem, Pericycle, endodermal, Forest, Desert, Xenogamy, Geitonogamy, Proteins, Mulberry, Castor, Papaya, Phytoplanktons, *Rhodospirillum*, *Chlorella*, *Agrobacterium*, *Gliocladium*, Vacuole, Chloroplast, Cambium, Monoecious, *Anabaena*).

(a) In prisere, in aquatic medium like ..... the pioneer plants are ..... .
(b) ..... growth is increase in girth. It is caused by ..... meristem.
(c) Transport of water from cortex to ..... is controlled by ..... cells.
(d) Maize and ..... are monoecious plants ..... is not possible but ..... is possible.
(e) Micro-organism like ..... acts as a pesticide, while ..... acts as a biofertilizer.

Ans. (a) Pond, phytoplanktons **(b)** Secondary, lateral
(c) Pericycle, endodermal **(d)** Castor, xenogamy, geitonogamy
(e) *Agrobacterium*, *Anabaena* *(CBSE 2009)*

C. MATCHING TYPE QUESTIONS :

Match the item in column A with suitable terms in column B :

Column A	Column B
(i) Secondary growth	(a) Sclerenchyma
(ii) Lignin	(b) Pits with small borders
(iii) Xylem	(c) *Nymphaea*
(iv) Fibre tracheids	(d) Bast fibres
(v) Epistomatic leaf	(e) Vascular cambium
(vi) Elongated root apex	(f) Dead
(vii) Flax fibres	(g) Chalk glands
(viii) Secondary xylem and secondary pholem	(h) Lateral meristem
(ix) *Tamarix*	(i) *Sagittaria*

ANSWERS

(i) (h); **(ii)** (a); **(iii)** (f); **(iv)** (b); **(v)** (c); **(vi)** (e); **(vii)** (d); **(viii)** (e); **(ix)** (g).

D. ASSERTION TYPE QUESTIONS :

These questions consist of two statements each, printed as *Assertion* and *Reason*. While answering these questions you are required do choose any one of the following four responses :

A. If both *Assertion* and *Reason* are true and the *Reason* is a correct explanation of the *Assertion*.

B. If both *Assertion* and *Reason* are true but *Reason* is not a correct explanation of the *Assertion*.

C. If *Assertion* is true but the *Reason* is false.

D. If both *Assertion* and *Reason* are false.

1. **Assertion.** Vessels are made up of row of cells placed one above the another with their intervening walls (septa) absent due to dissolution.
   Reason. Sieve tubes are tubular channels. In tracheids walls are thick.
   A **B** **C** **D**
2. **Assertion.** There is large deposition of lignin in the lumen of tracheids.
   Reason. The lumen of tracheids is narrow.
   A **B** **C** **D**
3. **Assertion.** Collateral bundles are found in stem dicotyledons and gymnosperms.
   Reason. Protoxylem and protophloem are located on separate radii.
   A **B** **C** **D**
4. **Assertion.** In dicot stem, vascular bundles are of open type.
   Reason. Dicot stem bears cambium in the vascular bundles.
   A **B** **C** **D**
5. **Assertion.** In monocot stem, vascular bundle are arranged in a ring.
   Reason. Stele is of dictyostele type.
   A **B** **C** **D.**
6. **Assertion.** Secondary xylem formed during spring is called spring wood and secondary xylem formed in autumn is called autumn wood.
   Reason. Spring wood and autumn wood is easily demarcated and leads to the formation of annual rings.
   A **B** **C** **D.**
7. **Assertion.** Quiescent centre is located in root-apex.
   Reason. Cells are highly lignified and are dead.
   A **B** **C** **D.**
8. **Assertion.** In bark all the cells are dead.
   Reason. Bark constitutes secondary cortex, epidermis, cork etc.
   A **B** **C** **D.**
9. **Assertion.** Vascular cambium is considered as lateral.
   Reason. It gives rise to lateral shoots.
   A **B** **C** **D.** ***(AIIMS 2000)***
10. **Assertion.** The quiescent centre acts as a reservoir of relatively resistant cells which constitute a permanent source of active initials
    Reason. The cells of the inactive region of quiescent centre become active when the previous active initials get damaged.
    A **B** **C** **D.** ***(AIIMS 2007)***
11. **Assertion.** In collateral vascular bundles, phloem is situated towards inner side.
    Reason. In monocot stem, cambium is present.
    A **B** **C** **D.** ***(AIIMS 2008)***

ANSWERS

1. (B); **2** (A); **3.** (C); **4.** (A); **5.** (D); **6.** (A); **7.** (C); **8.** (C); **9.** (C); **10.** (A); **11.** (D).

E. REASONING TYPE QUESTIONS :

Give reason for the following :

1. In pteridophytes, one cell constitute the meristem.
2. Primary meristems persist throughout the life.

3. Chlorenchyma is a type of parenchyma.
4. Sclerenchyma fibres and sclereids are both types of sclerenchyma.
5. In monocot roots and dicot roots, protoxylem lies towards inside of metaxylem.

ANSWERS

1. Because single cell meristem in pteridophytes constitute both promeristem and primary meristem.
2. Primary meristem is derived directly from meristems of embryo (promeristems i.e. tip of radicle and plumule)
3. Cells of chlorenchyma are chlorophyll containing parenchymatous cells. It consists mainly of thin walled cells.
4. Both are highly thickened due to deposition of lignin and cellulose. Both are dead at maturity.
5. It is due to exarch condition of xylem. Cells of protoxylem usually face passage cells of endodermis for easy entry of water from cortex to xylem.

E. ADDITIONAL MULTIPLE CHOICE QUESTIONS :

Choose the correct answer :

1. Intercalary meristem leads in :
   (a) Secondary growth (b) Primary growth (c) Apical growth
   (d) Secondary thickening (e) Secondary over growth
2. Vascular bundle is closed when :
   (a) Cambium present (b) Cambium absent
   (c) Pericycle absent (d) None of these
3. In dicot stem, vascular, bundles are :
   (a) Numerous scattered (b) Arranged in a ring
   (c) Without cambium (d) Surrounded by bundle sheath
4. Apical stem of shoot apex is :
   (a) Intercalary meristem (b) Lateral meristem
   (c) Primary meristem (d) Secondary meristem
5. Which of the following is not a character of meristematic tissue?
   (a) Presence of prominent nucleus (b) Presence of intercellular spaces
   (c) Absence of vacuole (d) Proplastid present
6. Which is living mechanical tissue?
   (a) Phloem (b) Parenchyma
   (c) Collenchyma (d) Sclerenchyma
7. Periderm is formed by :
   (a) Phellem (b) Phelloderm (c) Phellogen (d) All of these
8. In a woody dicotyledonous tree, which of the following parts will mainly consist of primary tissue?
   (a) All parts (b) Stem and root
   (c) Flowers, fruits and leaves (d) Shoot tip and root tip
9. Fascicular, interfascicular and extra-stelar cambium together constitute :
   (a) Ground meristem (b) Apical meristem (c) Intercalary meristem
   (d) Lateral meristem (e) Primary meristem
10. Intercalary meristem is located in :
    (a) Petiole and internode (b) Stem tip (c) Root (d) Bud
11. The cells which help in rolling and unrolling of leaf lamina in grasses are :
    (a) Complementary cells (b) Motor cells (c) Passage cells (d) Companion cells
12. Vascular bundles having phloem on periphery of outer and inner cambium are called :
    (a) Bicollateral open vascular bundles
    (b) Bicollateral, conjoint closed vascular bundles
    (c) Amphivasal, conjoint closed vascular bundles
    (d) Collateral, radial, open vascular bundles

13. Epiblema is characteristic of :
(a) Monocot roots (b) Dicot stems (c) Dicot roots (d) Monocot stems

14. Which one of the following statements pertaining to plant structure is correct?
(a) Cork lacks stomata, but lenticels carry out transpiration
(b) Passage cells help in transfer of food form cortex to phloem
(c) Sieve tube elements possess cytoplasm but no nuclei
(d) The shoot apical meristem has a quiescent centre

15. Cork tissue arises from :
(a) Periderm (b) Phellogen (c) Phelloderm (d) Phellem

16. Inner, darker and harder portion of secondary xylem that cannot conduct water, in an older dicot stem, is called
(a) Alburnum (b) Bast (c) Wood (d) Duramen

17. How a dicot leaf differs anatomically from a monocot leaf?
(a) Parallel venation
(b) Differentiation of palisade and spongy parenchyma
(c) Stomata only on upper side
(d) Stomata on both sides

18. Which of the following statement is true?
(a) Vessels are multicellular and with wide lumen
(b) Tracheids are multicellular and with narrow lumen
(c) Vessels are unicellular and with narrow lumen
(d) Tracheids are unicellular and with wide lumen

19. Rod-shaped elongated thick-walled lignified dead cells found in seed coat of pulses (legumes) are :
(a) Macrosclereids (b) Astrosclereids (c) Brachysclereids (d) Osteosclereids

20. Dicot root having more than six vascular bundles are found in :
(a) Pea (b) Sunflower (c) *Ficus* (d) *Ranunculus*

ANSWERS

1. (b);	**2.** (b);	**3.** (b);	**4.** (c);	**5.** (b);	**6.** (c);	**7.** (c);	**8.** (d);	**9.** (d);	**10.** (a);
11. (b);	**12.** (a);	**13.** (a);	**14.** (c);	**15.** (b);	**16.** (d);	**17.** (b);	**18.** (a);	**19.** (a);	**20.** (c).

Chapter Practice Test

Time Allowed : 1:30 Hours *Maximum Marks : 35*

1. Why cambium is considered to be a lateral meristem ? (1)
2. What is the function of companion cell ? (1)
3. What is protoxylen ? (1)
4. Define calyptrogens. (1)
5. Name the cells which make the leaves curl in plants during water stress. (1)
6. Write the functions of cortex region in monocot roots. (2)
7. What is origin of secondary phloem ? In which type of plants, it is present ? (2)
8. Why the endodermis in dicot stem is called starch sheath? (2)
9. How does cambial ring is formed in dicot stem ? (2)
10. List out the functions of ground tissue system. (2)
11. Differentiate between periderm and bark. (3)
12. Differentiate between sap root and heart wood. (3)
13. Describe briefly the anatomy of a young dicot root. (3)
14. How annual rings are formed ? (3)
15. Discuss the constituents of xylem. (3)
16. How the study of plant anatomy is useful to us ? (5)

❑❑❑

To check your performance, see ANSWERS TO CHAPTER PRACTICE TEST at the end of Part I of the book.

CHAPTER 7

STRUCTURAL ORGANISATION IN ANIMALS

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- Understanding Text 1
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CHAPTER PRACTICE TEST 97

CELL

It is the **structural and functional unit of life.** A cell is a mass of protoplasm surrounded by a plasma membrane. Cells vary widely in shape and size. There are 200 different types of specialized cells in the human body. The protoplasm of cell is generally with a central spherical **nucleus** and a variety of cytoplasmic living **cell-organelles** like the endoplasmic reticulum, mitochondria, Golgi bodies, centrioles, ribosomes, lysosomes, etc. Each cell organelle performs a specific function. In unicellular organisms e.g., *Amoeba*, all the functions are performed by single cell.

TISSUE

A group of cells similar in form, structure and embryonic origin which coordinate to perform a specific function along with their intercellular material is called a **simple tissue**, while a group of cells, different in their structure and function but coordinating to perform a specific function, is called a **compound tissue.** Tissues are required in the multicellular organisms for not only **division of labour**, but also for the **integration and cooperative biological processes** to improve their efficiency and to increase their chances of survival. Term tissue has been derived from the French word "**tisser**" which means "**a belt of woven**."

The branch of science that deals with the microscopic study of tissues, is called **histology** (Gr. *histos* = tissue; *logos* = study).

TYPES OF TISSUES

Depending on the basis of their **structure and function**, tissues are of four types — **Epithelial (covering) tissues** (for protection), **Muscular (contractile) tissues** (movements and locomotion), **Connective (supporting) tissues** (binding different structures of body) and **Nervous tissues** (conduction of nerve impulses). All these tissues originate from one or more type of primary germ layers of gastrula. All the complex animals consist of these four basic types of tissues, which are organised in specific proportion and pattern to form specific organs, each of which performs specific function with more efficiency and better coordination.

I. EPITHELIAL TISSUES

(Gr. *epi* = upon; *thele* = nipple)

1. General position. It covers the outer surface of all the organs of body and also lines the cavities of all the hollow organs of body.

2. General structure

(a) Cells are arranged in one or more **layers**.

(b) Cells are **compactly arranged** and there is **no or very little intercellular matrix** between them.

(c) Cells of lowermost layer always rest on a non-living **basement membrane (or basal lamina)**.

(d) Cells may originate **from any primary germ layer** (*e.g.*, epidermis of skin from ectoderm; coelomic epithelium from mesoderm; and mid gut epithelium from endoderm) and are **non-vascular**, so get nutrition by diffusion from the blood capillaries present in underlying connective tissue.

(e) Cells have the power of **division and regeneration** throughout life.

(f) Free surface of the cells may be smooth, or may have fine hair like cilia or microvilli.

(g) Between the epithelial cells, there are three types of junctional complexes :

- **Tight junctions** which prevent the leakage of substances;
- **Adhering junctions** which cement the adjoining cells e.g. desmosomes, interdigitation; etc. and
- **Gap junctions** which allow the movement of ions and biomolecules between adjoining cells.

3. General functions. Epithelial tissue covers and protects underlying tissues from mechanical injuries (*e.g.* skin); entry of germs; forms useful derivatives like nails, scales, feathers, claws, hair, hoofs and horns; secretion from epithelial glands; respiration in frog; skin pigmentation by melanin containing melanophores; absorption from intestine; excretion of wastes in kidney tubules; sensation **(neuroepithelium)** in the sense organs.

4. Types of Epithelial tissues. On the basis of their **structure and function,** epithelia are divided into **two main groups :**

A. Covering epithelial.

B. Glandular epithelia.

A. Covering epithelial. These epithelial tissues either cover the external surfaces or line the cavities of internal organs of the body.

Depending upon the **number of layers of cells,** epithelial tissues are of **two types :**

1. Simple or Unstratified or Unilaminar epithelia (one-layer thick); and

2. Compound or Multilaminar epithelia (many-layers thick).

1. Types of Simple epithelia. These cover the areas with less wear and tear e.g. secretory and absorptive surfaces ; and lining of body cavities and ducts. Being thin walled, these are not effective in protecting underlying tissues so do not cover surfaces. These are of three types on the basis of **shape of the cells** and **position of nucleus** :

***(i)* Squamous epithelium (Figs. 1 & 2)**

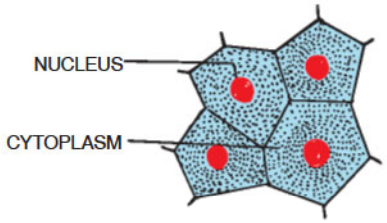


Fig. 1. Squamous epithelium (Surface view).

Structure. It is formed of thin, flat, discoidal and polygonal cells which fit like the tiles in a floor, so also called **pavement epithelium.** Nucleus is transverse and oval, present in middle thicker part of the cell **(Fig. 2)**.

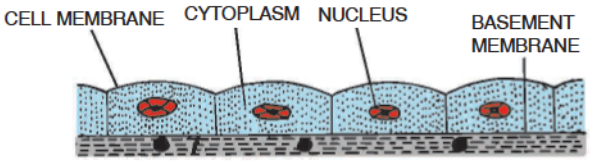


Fig. 2. V.S. Squamous epithelium.

Position and Function. It is found in the **alveoli** of lung for exchange of gases; in **Bowman's capsule** of nephron for ultrafiltration; in blood capillaries called **endothelium** and lines the coelom where it is called **mesothelium**. It also lines the **descending limb of Henle's loop of nephron** and eyelids.

***(ii)* Cuboidal epithelium (Figs. 3 and 4)**

Structure. It is formed of polygonal and cuboidal cells. Nucleus of each cell is rounded and centric. It is primarily meant for secretion and absorption.

Types. Cuboidal epithelium is of **four types** (Table 1).

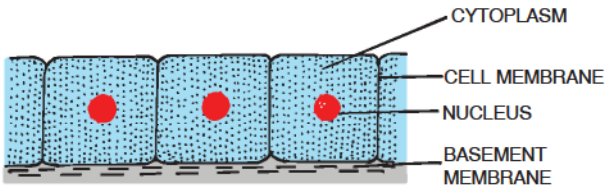


Fig. 3. V.S. Cuboidal epithelium.

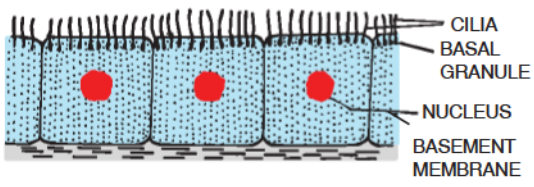


Fig. 4. V.S. Ciliated cuboidal epithelium.

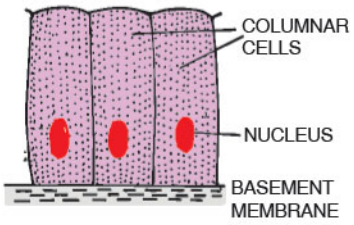


Fig. 5. V.S. Columnar epithelium.

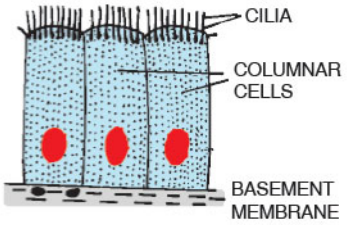


Fig. 6. V.S. Ciliated columnar epithelium.

Table 1. Types of Cuboidal Epithelia.

Type	Characters	Position	Function
(A) **Ciliated cuboidal epithelium (Fig. 4)**	Free surface of each cell is with fine hair-like cilia, each arising from a basal granule.	Some parts of body of nephron.	**Movement of nephric filtrate** by beating of cilia.
(B) **Pigmented cuboidal epithelium**	Cytoplasm is with granules of melanin pigment.	Choroid and a part of retina of eye.	**Absorption of light.**
(C) **Germinal epithelium**	Cells are germinal in nature.	Seminiferous tubules of testes. Also lines ovaries.	Undergoes meiosis to **form gametes** (sperms and ova).
(D) **Brush-bordered cuboidal epithe-ium**	Free surface of cells with microvilli.	Proximal convoluted tubule (PCT) of body of nephron.	Increased **reabsorption of useful materials** from nephric filtrate into blood.

(iii) **Columnar epithelium (Fig. 5)**

Structure. It is formed of tall, pillar–like cells lying side by side and are polygonal in surface view. Nucleus is longitudinally oval and generally lies toward the base **(Fig. 5).** It is mainly present in secretory and absorptive tissues so are meant for secretion and absorption.

Types. Columnar epithelium is of **three types** (Table 2) :

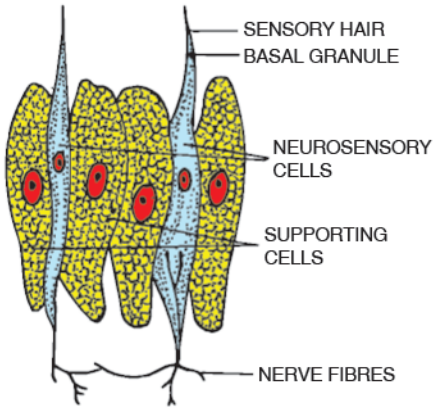


Fig. 7. V.S. Sensory columnar epithelium.

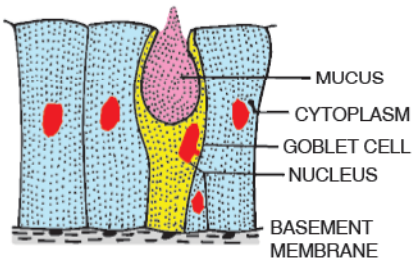


Fig. 8. V.S. Glandular columnar epithelium.

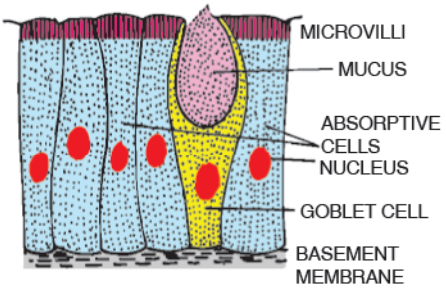


Fig. 9. V.S. Brush-bordered epithelium.

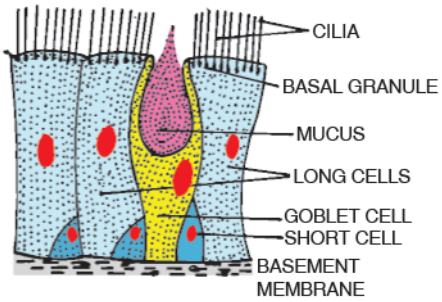


Fig. 10. Pseudostratified epithelium.

2. Compound epithelia. These are many layered and are found in the regions with rapid wear and tear i.e., where rapid replacement is needed. These have no major role in secretion and absorption but are **mainly protective** (from mechanical, chemical, thermal or osmotic stress) in function e.g. on the skin. Only lowermost layer rests on basement membrane.

On the basis of **number of layers of cells** and their **stretching ability**, compound epithelia are of two types :

Table 2. Types of Columnar Epithelia.

Type	Characters	Position	Functions
(a) **Ciliated columnar epithelium (Fig. 6)**	Free surface of cells have hair-like cilia, each arising from a basal granule.	**Fallopian tubes** in female.	Movement of ovum or zygote towards the uterus.
(b) **Brush-bordered columnar epithelium (Fig. 9)**	Some columnar cells as goblet cells, while other columnar cells with microvilli at free surface.	Mucosa of intestine.	Microvilli increase surface area for absorption of food and water.
(c) **Pseudostratified columnar epithelium (Fig. 10)**	Single layered columnar epithelium but appears two-layered as it is with two types of cells. Tall cells may have cilia on free surface and short cells not reaching upto free surface.	Trachea and primary bronchi; and ducts of parotid salivary glands..	Cilia beat outward to expel any dust or bacterium trapped by mucus of goblet cells.

Table 3. Differences between Squamous, Cuboidal and Columnar epithelia.

Character	Squamous epithelium	Cuboidal epithelium	Columnar epithelium
1. **Shape of cells**	Flat, discoidal and polygonal.	Cube-like and polygonal.	Tall pillar-like and polygonal.
2. **Nucleus**	Transversely oval and in the middle swollen part of cell.	Rounded and centric.	Longitudinally oval and towards basal part of cell.
3. **Position**	**Glomerulus** of nephron of kidneys; **Alveoli** of lungs; blood capillaries, etc.	Some parts of the body of nephron; retina of eye; germinal epithelium of testis and ovary, etc.	Fallopian tubes; nasal chambers; mucosa of intestine; trachea; etc.

(i) Stratified epithelia, and **(ii) Transitional epithelia.**

(i) **Stratified epithelium (Figs. 11 & 12).** These are formed of several layers of cells (usually 5-8), lying one upon the other. The nature of cells of different layers is different. The lowermost layer is a columnar epithelium resting on a basement membrane. It is germinal in nature, divides by mitosis, produces new cells which are pushed upward. It is called **stratum germinativum** or **stratum Malpighi.** The cells during their upward movement undergo certain changes. Depending upon the **nature of cells of the outermost layer,** stratified epithelium is of four types (Table 4):

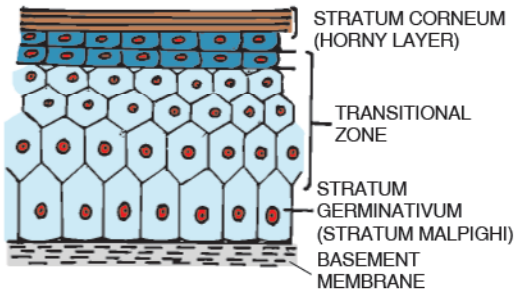


Fig. 11. Stratified squamous (keratinised) epithelium.

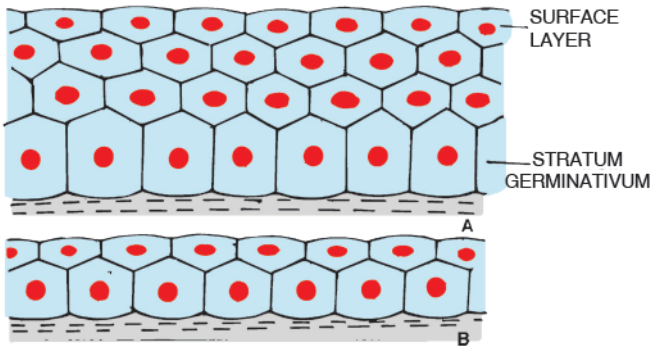


Fig. 12. Transitional epithelium. **A.** Relaxed. **B.** Stretched.

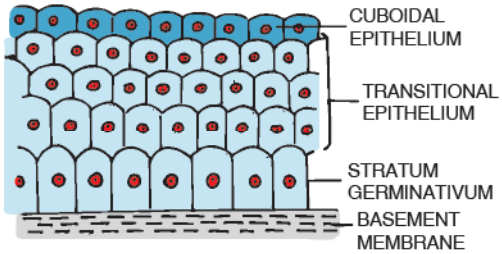


Fig. 13. Stratified cuboidal epithelium.

Table 4. Types of Stratified Epithelia.

Type and structure	Occurrence
(a) **Stratified keratinized (cornified) squamous epithelium (Fig. 11).** The cells undergo **flattening** and **keratinisation** or **cornification** (living cytoplasm is gradually replaced by a water proof, scleroprotein **keratin or horn**). The outermost layer is formed of dead and flat cells and is called **stratum corneum (horny layer)**. The region of epithelium between stratum germinativum and stratum corneum is called **transitional zone**. Stratum corneum undergoes periodic moulting.	Forms **epidermis of skin of tetrapods.** It prevents loss of water and protects from mechanical injuries. In vertebrates, the nails, hair, horns, claws and feathers are also derived from it.
Non-keratinized (or parakeratinized) stratified squamous epithelium. In this, cells of superficial layer are thin walled, flat and are nucleated (pyknotic or condensed).	Cornea of eye, buccal cavity, tongue, lower part of pharynx, oesophagus and vagina.
(b) **Stratified cuboidal epithelium (Fig. 13).** Outward moving cells undergo little flattening and keratinisation so stratum corneum is formed of living and cuboidal cells having nuclei.	Forms **epidermis of skin of fishes and many urodeles**. It also lines **conjunctiva** of eye ; female urethra and ducts of sweat and pancreatic glands.
(c) **Stratified columnar epithelium(Fig. 14).** Cells of outermost layers are also columnar.	Lines the **male urethra.**
(d) **Stratified ciliated columnar epithelium (Fig. 15).** Outermost layer is formed of ciliated columnar cells.	Lines **larynx** and **soft palate.**

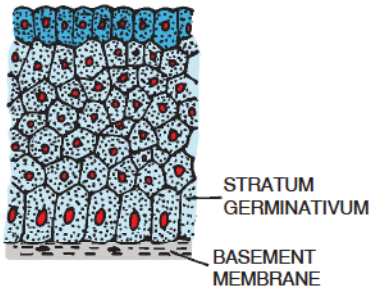


Fig. 14. Stratified columnar epithelium.

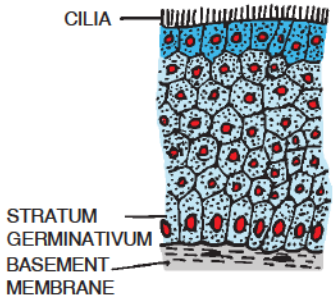


Fig. 15. Stratified ciliated columnar epithelium.

(ii) **Transitional or plastic epithelium (Fig. 12).** It is much thinner and more stretchable than the stratified epithelium. It is formed of a few layers of cells (4-5 layers) but there is no basement membrane. Basal layer is formed of cuboidal cells while the superficial layer is formed of rectangular or oval-shaped cells. When stretched, it reduces to 2 or 3 layers of cells. It is found in **ureters, urinary bladder** and **renal pelvis** which can expand considerably to store urine.

Three Special types of epithelia :

(i) Neuroepithelium (Fig. 7). It is a specialized columnar epithelium of taste buds of tongue, olfactory epithelium of nasal chambers and organ of Corti of internal ear. The cells have sensory hair at their free ends and nerve fibres at other ends. It is specialised for sensory functions like tasting, smelling, hearing, etc.

(ii) Myoepithelial cells. These are specialized epithelial cells which become branched and have contractile muscle proteins, **myosin** and **actin,** in their cytoplasm. Their contraction stimulates the salivary glands, mammary glands and sweat glands to release saliva, milk and sweat respectively.

Table 5. Differences between Stratified epithelium and Transitional epithelium.

Character	Stratified epithelium	Transitional epithelium
1. **No. of layers**	More, usually 5–8.	Less, usually 4–5.
2. **Basement membrane**	Present.	Absent.
3. **Nature of basal layer**	Columnar cells.	Cuboidal cells.
4. **Position**	Epidermis of skin of tetrapods.	Urinary bladder and ureters.
5. **Function**	Protection from mechanical injuries and loss of water.	Distension of urinary bladder for temporary storage of urine.

Table 6. Differences between Simple epithelium and Compound epithelium.

Character	Simple epithelium	Compound epithelium
1. No. of layers	Only one, so called **unilaminar**.	Many layered, so called **multilaminar**.
2. Position	Found in areas with less wear and tear e.g. lining of blood capillaries, body cavity etc.	Found in areas with more wear and tear e.g. skin, buccal cavity, pharynx, etc.
3. Function	Secretion, absorption, sensation etc.	Mainly protection from chemical and mechanical stresses.

(iii) Glandular epithelia (Fig. 8). These are specialised cuboidal or columnar epithelial cells that form the glands. Glands secrete useful chemical substances. **So glands are always epithelial in origin.**

TYPES OF GLANDS

1. On the basis of number of cells, glands are of **two types :**

(a) **Unicellular glands (Fig. 16).** These are one celled glands commonly found in mucosa of stomach and intestine. Also found in lining of trachea and nasal chambers. These are called **Goblet** or **chalice cells.** These are modified columnar cells and secrete **mucus** which lubricates the food for easy peristalsis.

(b) **Multicellular glands (Fig. 17).** These are formed of many cells and are generally located in underlying connective tissue (*e.g.*, dermis). These are formed by invagination of epithelia. A multicellular gland having a single unbranched duct (e.g. crypts of Lieberkuhn of small intestine, and sweat and oil glands of skin of mammals) is called **simple gland**, while a multicellular gland having a branched duct system (e.g. mammary glands, and Brunner's glands of small intestine) are called **compound glands.**

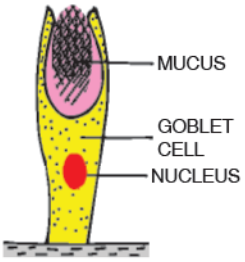


Fig. 16. Unicellular gland.

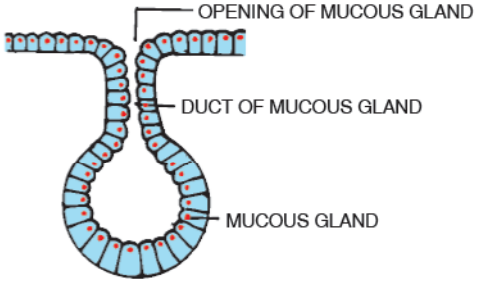


Fig. 17. Multicellular gland.

Table 7. Outline classification of Covering Epithelia.

Covering or Epithelial Tissues

- **Simple Epithelia** (one layer of cells)
  - on the basis of shape of cells — 3 types
    - **Squamous Epithelium**
    - **Cuboidal Epithelium**
      1. Ciliated cuboidal epithelium
      2. Pigmented cuboidal epithelium
      3. Germinal cuboidal epithelium
      4. Brush-bordered cuboidal epithelium
    - **Columnar Epithelium**
      1. Ciliated columnar epithelium
      2. Brush-bordered columnar epithelium
      3. Pseudostratified columnar epithelium
- **Compound Epithelia** (several layers of cells)
  - **Stratified Epithelium**
    1. Stratified squamous epithelium
    2. Stratified cuboidal epithelium
    3. Stratified columnar epithelium
    4. Stratified ciliated columnar epithelium.
  - **Transitional Epithelium**

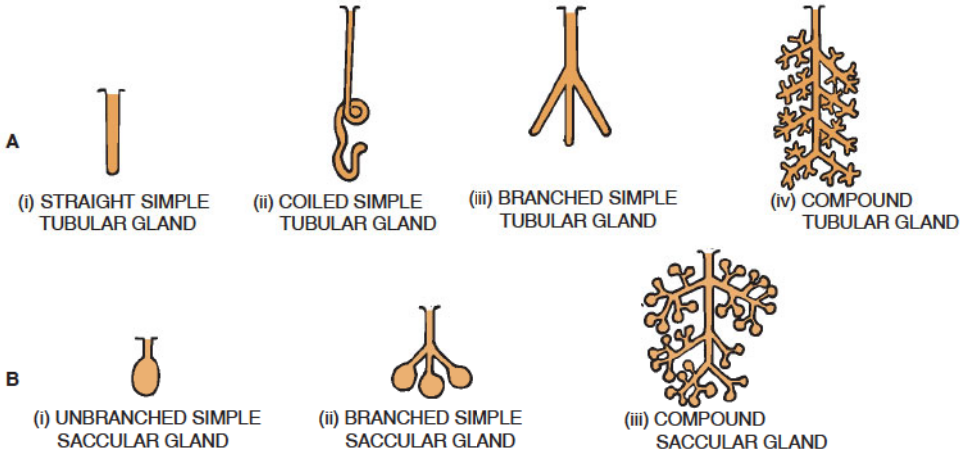


Fig. 18. Multicellular glands. (**A**) Types of tubular glands. (**B**) Types of saccular glands.

2. On the basis of shape of their secretory part, multicellular glands are of **two types** ;

(*a*) **Tubular glands (Fig. 18 A).** These are tubular-shaped with uniform diameter. These are of following types :

(*i*) **Simple straight tubular glands** *e.g.*, crypts of Lieberkuhn of intestine and in nuptial (copulatory) pads of male frog.

(*ii*) **Simple coiled tubular glands** *e.g.*, sweat glands in the skin of mammals.

(*iii*) **Simple branched tubular glands** e.g., gastric glands of stomach and sweat glands of armpit.

(*iv*) **Compound tubular glands.** Each is formed of branched and rebranched tube-like duct *e.g.*, Brunner's glands in submucosa of duodenum and milk glands of Prototherians (egg-laying mammals).

(*b*) **Saccular (Acinal or Alveolar) glands (Fig. 18 B).** Each saccular gland is differentiated into lower spherical secretory part called **acinus of alveolus** and upper narrow tubular duct. These are of following types:

(*i*) **Simple saccular glands** *e.g.*, mucous glands in skin of frog and poison glands in skin of toad.

(*ii*) **Simple branched saccular glands** *e.g.*, sebaceous (oil) glands in human skin.

(*iii*) **Compound saccular glands.** Each is formed of branched and rebranched duct, each ductule forming acinus at the end *e.g.*, mammary glands in human female and sub-lingual and sub-maxillary salivary glands.

(*iv*) **Compound tubulo-alveolar glands** *e.g.* parotid salivary glands and pancreas.

3. On the basis of mode of secretion, glands are of **three types :**

(*a*) **Merocrine or epicrine glands.** These release only their secretion by diffusion and no structural change occurs in the glands e.g. **pancreas, liver, goblet cells, sweat glands,** and **salivary glands.**

(*b*) **Apocrine glands.** In this glands, the apical parts of glands are also discharged along with their secretion e.g. **mammary glands.**

(*c*) **Holocrine glands.** In these, whole gland bursts along with the secretion and is regenerated *e.g.* **oil (or sebaceous) glands** in the skin of mammals.

4. On the basis of presence of duct, glands are of **three types :**

(a) **Exocrine glands (Fig. 19).** These are those glands which send their secretions to their sites of action through some ducts so also called **ducted glands** or **glands of external secretion.** *e.g.*, **salivary glands** (salivary ducts), **liver** (bile duct), **sweat glands** (sweat ducts), **mammary glands** (mammary ducts), **ear wax glands,** etc.

(b) **Endocrine glands (Fig. 20).** These are **ductless** glands which secrete hormones generally into the blood which transports them to their target organs so also called **glands of internal secretion.** *e.g.*, **thyroid, parathyroid, pituitary, adrenal glands,** etc.

(c) Heterocrine or mixed glands. These are partly exocrine (release secretions into some duct) and partly endocrine (release hormones into the blood) *e.g.*, **Pancreas.**

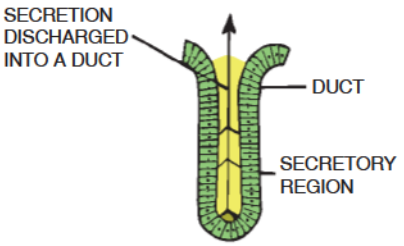


Fig. 19. Exocrine gland.

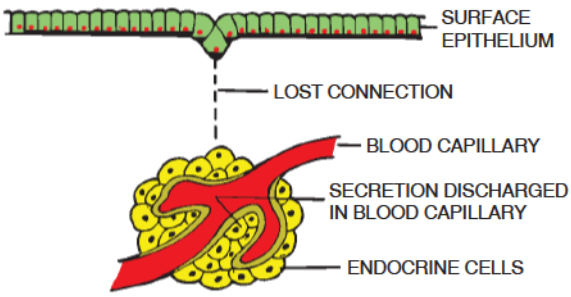


Fig. 20. Endocrine gland.

COMPETITION PLUS

- **Histogenesis :** Process of differentiation of tissues.
- **Histolysis :** Process of degeneration of tissues.
- **F. Xavier Bichat (1801) :** Gave the term tissue. He is also called **"Father of Histology".**
- Outermost layer of epidermis of skin of frog is also squamous epithelium.
- **Basement membrane** is formed of outer **basal lamina** of mucopolysaccharides and glycoproteins; and inner **fibrous** or **reticular lamina** of collagen or reticular fibres.
- **Mucous membrane (mucosa) :** The epithelium containing **(numerous)** mucus-secreting goblet cells e.g. lining of stomach and intestine.
- **Ciliated epithelium** is of two types — Ciliated cuboidal and ciliated columnar epithelia.
- **Ciliated columnar epithelium** also lines Bronchioles, tympanic cavity of middle ear and Eustachian tube.
- **Schneiderian membrane.** Another name of olfactory epithelium.
- **Serous cells** are those unicellular glands which secrete a clear – watery fluid and are found in sweat glands, intestinal glands, etc.

TYPES OF CILIA

Cilia are fine vibratile cytoplasmic processes present on free surface of epithelial cells of ciliated epithelium. These are of **two types (Fig. 21)** :

1. Kinocilia. These are motile and arise from cytoplasmic basal granules. These are present on respiratory epithelial cells and ependymal cells lining the central canal of spinal cord.

2. Stereocilia. These are non – motile and are evaginations of plasma membrane. These are present on the epithelial cells of epididymis and vasa deferentia.

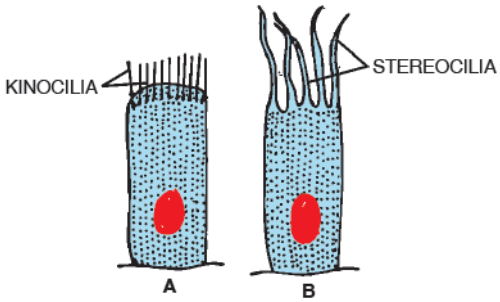


Fig. 21. A. Kinocilia; **B.** Stereocilia.

PRACTICE PROBLEMS – EPITHELIAL TISSUE

1. Define histology.
2. List two structural properties of epithelial tissue.
3. Why is squamous epithelium called pavement epithelium?
4. Give the position and function of germinal epithelium.
5. Where is brush-bordered cuboidal epithelium located? What is its function?
6. Give the position and function of pseudostratified epithelium.
7. Why is tracheal epithelium called pseudostratified epithelium?
8. What are stereocilia?
9. List two peculiar features of transitional epithelium.
10. What is keratinisation?
11. Why is gut mucosa with large number of goblet cells?
12. Give the position of compound tubular and compound saccular glands.
13. List one example of each of exocrine, endocrine and heterocrine glands.
14. What is heterocrine gland?
15. How do holocrine and merocrine glands differ from each other?

ANSWERS TO PRACTICE PROBLEMS

1. Microscopic study of tissues.
2. (i) cells are very closely arranged in one or more layers.
   (ii) cells can divide and regenerate throughout life.

3. In this epithelium, the cells are flat, discoidal and fitted like the tiles in a floor.
4. Germinal epithelium lines ovary and seminiferous tubules of testis. The cells divide by meiosis and form the gametes.
5. It is present in proximal convoluted tubule of nephrons of kidney. Microvili increase the surface area for selective reabsorption of useful materials from nephric filterate.
6. It is found in trachea and primary bronchii. Their cilia beat outward to expel dust particles or bacteria trapped by mucus secreted by goblet cells.
7. It is a unilaminar but appears two layered as is with two types of cells : Tall cells and short cells.
8. These are non-motile evaginations of cell membrane. These are found in epididymis and vas deferens.
9. The cells are arranged in 4 to 5 layers but is highly stretchable and may be in 2 to 3 layers. It does not rest on a basement membrane.
10. Deposition of keratin in the cytoplasm of cells is called keratinisation. It makes the layer water proof and germ proof.
11. Goblet cells secrete mucus which lubricates the food for easy peristalsis.
12. (i) Compound tubular glands are **Brunner's glands** in the submucosa of duodenum.
    (ii) Compound saccular glands are **mammary glands** of placental mammals.
13. (i) Exocrine glands = Liver ; (ii) Endocrine gland = Thyroid ; (iii) Heterocrine gland = Pancreas.
14. It is partly exocrine (with duct) and partly endocrine (without duct).
15. Holocrine gland is lost with secretion (e.g. oil gland) while merocrine gland releases only its secretion but is not lost (e.g. goblet cells).

ADDITIONAL USEFUL INFORMATIONS ABOUT TISSUE, EPITHELIAL TISSUE AND EPITHELIAL GLANDS FOR COMPETITIVE EXAMINATIONS

- *Histology : Also called microscopic anatomy, deals with the study of tissues. It was founded by Marcello Malpighi (commonly called Father of Animal Histology) while term histology was coined by Mayer.*
- *Study of tissue in connection with disease is called histopathology.*
- *Ruysch : Coined the term epithelium from two Greek words (epi = upon, thelio = grow).*
- *Epithelial tissue was first to evolve in kingdom Animalia.*
- *Tesselated epithelium : Endothelium in which cells have wavy margins e.g. lines the blood capithelium and mesothelium.*
- *Keratin : A scleroprotein which is waterproof and forms stratum corneum and forms epidermal scales of reptiles, feathers, hair, nails, claws, hoofs and horns.*
- *Transitional epithelium : Also called plastic epithelium or urothelium. It lacks basement membrane.*
- *Tanning : Chemical treatment of dermis of skin of large mammals to provide leather.*
- *Sweat glands : Maximum on the forehead while absent from the margins of lips.*
- *Sensory columnar epithelium of taste buds, nasal chamber and internal ear is respectively called gustatory epithelium, olfactory epithelium and stato-acoustic epithelium.*

II. MUSCULAR TISSUES

Origin. Muscular tissues are generally **mesodermal** in origin. These form all the muscles of an animal body.

General structure

1. Muscle cells are highly elongated and contractile and are called **muscle fibres** (also called **myocytes**).

2. These can contract along their longitudinal axis upto one-third or one-half of their length.

3. The cytoplasm of the muscle fibres, called **sarcoplasm**, is highly contractile. It has numerous mitochondria collectively called **sarcosomes**, a network of modified SER called **sarcoplasmic reticulum** and numerous glycogen granules to provide energy.

4. Sarcoplasm also contains large number of fine longitudinal, parallel and contractile proteinaceous threads called **myofibrils.**

5. These have **no power of division and regeneration.**

General functions of Muscular tissue

1. It is responsible for **movements** of body parts.

2. It maintains **equilibrium**.

3. It helps in **collecting informations** about changes in external environment.

4. It brings about movement of food in digestive tract, urine in ureters, sperms in vas deferens and ovum in Fallopian tube by **peristaltic movements**; production of sound, beating of heart for blood circulation, respiratory movements to inhale fresh air and exhale foul air in and out of lungs etc.

5. It provides **support** to skeletal structures.

6. It helps in variety of methods of **locomotion** of living organisms.

7. It also controls **facial expression** and gesture.

TYPES OF MUSCULAR TISSUES

There are three major classes of muscular tissues :

A. Striated (or striped or skeletal or voluntary) muscles.

B. Smooth (or unstriated or visceral or involuntary) muscles.

C. Cardiac muscles.

A. STRIATED MUSCLES (FIG. 22)

1. Position. They are found in limbs, tongue, abdominal wall, pharynx and upper 1/3rd part of oesophagus.

2. Structure

(*a*) **Arrangement.** In a striated muscle (e.g. biceps), the muscle fibres are arranged parallel in bundles called **fasciculi (Fig. 22A)** and are held together by connective tissue layer called **fascia**.

(*b*) Each muscle fibre is long, **cylindrical**, straight, unbranched and has blunt ends.

(*c*) A muscle fibre is about **40 mm** in length and **10-100 µm** (one µm=0.001 mm or 10^{-6} metre) in diameter.

(*d*) A striated muscle fibre is externally covered by a special membrane, called **sarcolemma**. Sarcolemma invaginates to form a system of **T–tubules.**

(*e*) Sarcoplasm is with numerous large sized mitochondria and glycogen granules as these muscle fibres have high energy requirements. It is also with a network of ER called **sarcoplasmic reticulum** which acts as a storehouse of calcium.

(*f*) It is **multinucleate (syncitial).** Nuclei are spindle shaped, peripheral and lie near the sarcolemma.

(*g*) Under light microscope, each **myofibril** or **sarcostyle** of striated muscle fibre appears to be formed of alternate **light and dark cross bands (Fig. 22B).**

(*h*) A dark band, also called **anisotropic** or **A-band**, has a light zone at the centre, called **Hensen's line** or **H-zone** while a light band, also called **Isotropic** or **I-band**, has a dark fibrous membrane at the centre, called **Krause membrane or Z-(Zwischenscheibe) line.**

(*i*) Dark bands of adjacent myofibrils lie side by side. Similarly, light bands of adjacent myofibrils also lie side by side, so forming striations or stripes and so called **striated** or **striped muscle fibres.**

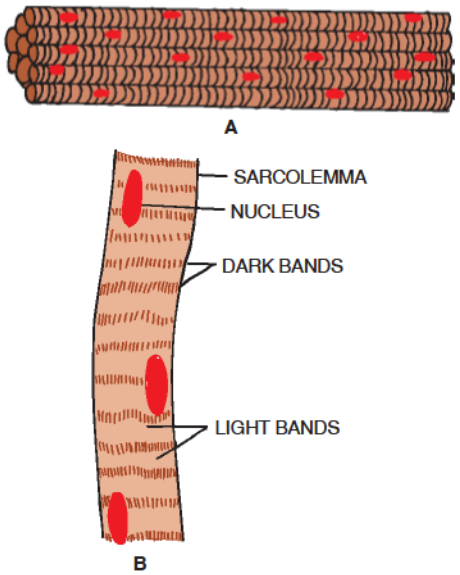


Fig. 22. Striated muscle fibres. **A.** Bundle of striated muscle fibres. **B.** Single striated muscle fibre.

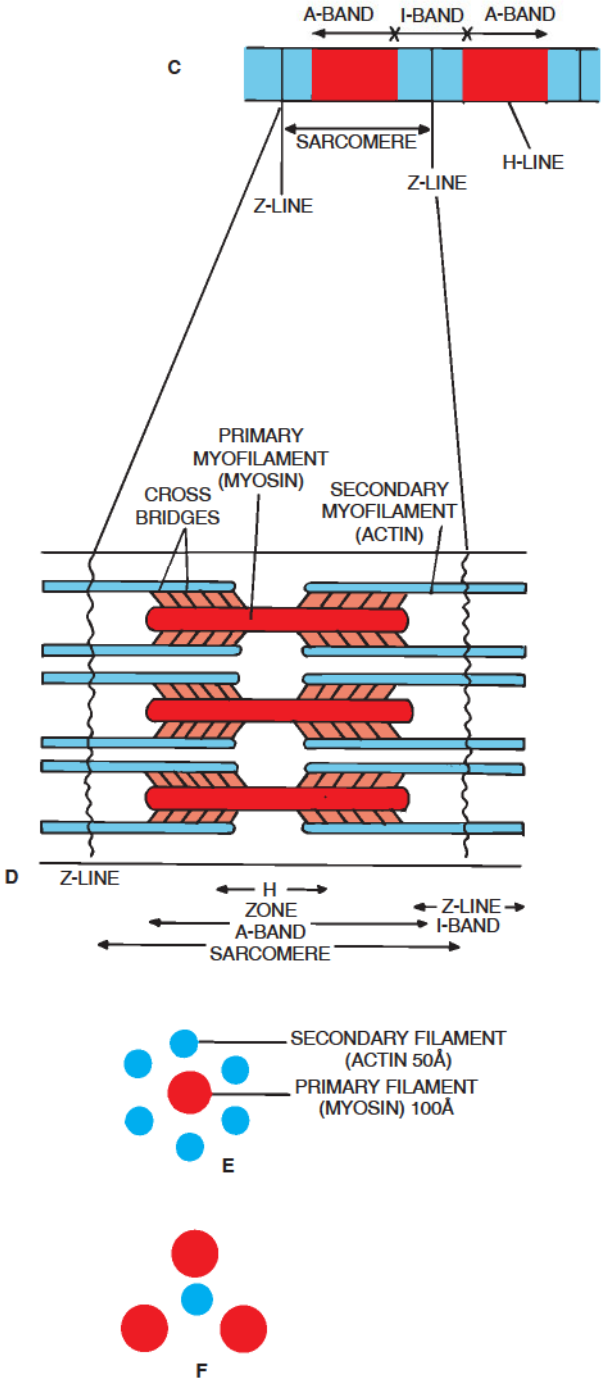


Fig. 22. C. Portion of Myofibril. **D.** Ultrastructure of a Sarcomere. **E.** Hexagon; **F.** Trigon.

Table 8. Differences between A- and I-Bands.

Character	A-Band	I-Band
1. Birefringence	It is **anisotropic.**	It is **isotropic.**
2. Appearance	Dark appearance.	Light appearance.
3. Central zone	Light **Hensen's line** or **H-zone.**	Dark **Krause's membrane** or **Z-line.**
4. Filaments	Formed of myosin and actin filaments.	Formed of only actin filaments.

(j) The part of myofibril between two adjacent Z-lines is known as **sarcomere**. It is the **structural and functional unit of striated muscle fibre** and is formed of one complete A-band and half of I-band on either side.

(k) Under the electron microscope, A-band is formed of thick **myosin** or **primary** or **A-filaments**. Each myosin filament is about 1.2 µm long and 100 Å in diameter and is formed of about 200 myosin protein molecules. It is free at both the ends and has small ridges called **cross bridges** or **heads**. Myosin filaments are interconnected and hold together by a thin fibrous membrane called **M-line**. I-band is formed of thin **actin** or **secondary** or **I-filaments.** Each actin filament is about 2 µm long and 50 Å in diameter and is formed of about 3,000 actin protein molecules. It is attached to the Z-line on one side while partially overlaps the myosin filament on other side. It has no cross bridges **(Fig. 22D).** The myosin and actin filaments are so arranged that six actin filaments surround each myosin filament **(Fig. 22E)** and form a **hexagon** while three myosin filaments surround each actin filament and form a **trigon (Fig. 22F)**.

(l) The striated muscle fibres are **highly vascular.**

(m) These are supplied by **central nervous system**.

(n) These are always under the conscious control of the will of the animal, so also called **voluntary muscles.**

(*o*) These are generally attached to the bones by tendons, so called **skeletal muscles.**

3. Mode of contraction. The striated muscle fibres undergo rapid and powerful contraction, but not for long periods, as these soon get fatigued (so also called **fatigue muscles**). These control skeletal movement of body parts and locomotion.

B. SMOOTH MUSCLE FIBRES (FIG. 23)

1. Position. These are present in the walls of visceral organs like alimentary canal, blood vessels, urinary bladder, ureters, genital ducts etc., so are also called **visceral muscles.** These are also present in hair muscles (arrector pili) of skin, iris and ciliary body of eye.

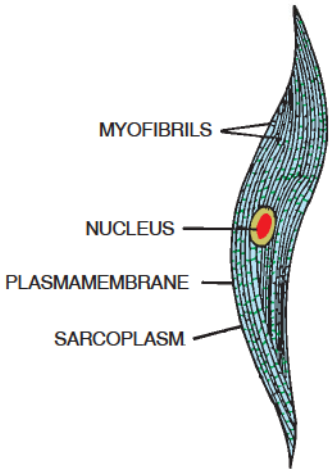


Fig. 23. Unstriated (smooth) muscle fibre.

2. Structure

(*a*) These are usually arranged in layers forming sheets in the wall of visceral organs.

(*b*) These are small sized (0.02—0.05 mm in length), spindle (fusiform) shaped having tapering ends.

(*c*) It is externally covered by **plasma membrane.**

(*d*) The number and size of mitochondria and glycogen granules are less.

(*e*) It is **uninucleate**. Nucleus is oval and centric.

(*f*) The myofibrils do not form dark and light bands, so are called **unstriated** or **unstriped** or **smooth** muscle fibres.

(*g*) The myofibrils are formed of randomly arranged myosin and actin filaments.

(*h*) These are less vascular and are supplied by autonomic nervous system.

(*i*) These are not under the will of an animal, hence called **involuntary muscles**. These are not attached to skeletal structures, so also called **non-skeletal** muscles.

3. Mode of contraction. The smooth muscle fibres contract slowly, but for a long period without undergoing fatigue, so also called **non-fatigue** muscles. These help in **peristalsis** in the visceral organs.

Table 9. Differences between Myosin and Actin filaments.

Character	Myosin filaments	Actin filaments
1. Occurrence	Found in only A-band.	Found in I-band and also project in A-band.
2. Thickness	Thicker (100Å)	Thinner (50Å)
3. Number	1,500 myosin filaments per myofibril.	3,000 actin filaments per myofibril.
4. Molecular weight	470,000 daltons.	46,000 daltons.
5. Cross bridges (Heads)	Present.	Absent.

4. Two types of smooth muscles (Table 10):

Table 10. Differences between Single-unit and Multi-unit smooth muscles.

Character	Single-unit (Unitary)	Multi-unit
1. Occurrence	Found in the wall of visceral organs like digestive tract, blood vessels, urinary and genital ducts etc.	Found in arrector pili (Hair muscle). Also iridial and ciliary muscles of eye.
2. Cytoplasmic bridges	Present, so are joined together.	Absent, so found individually.
3. Mode of contraction	Contract rhythmically as a single unit (**Syncitium**).	Contract independently as separate unit.

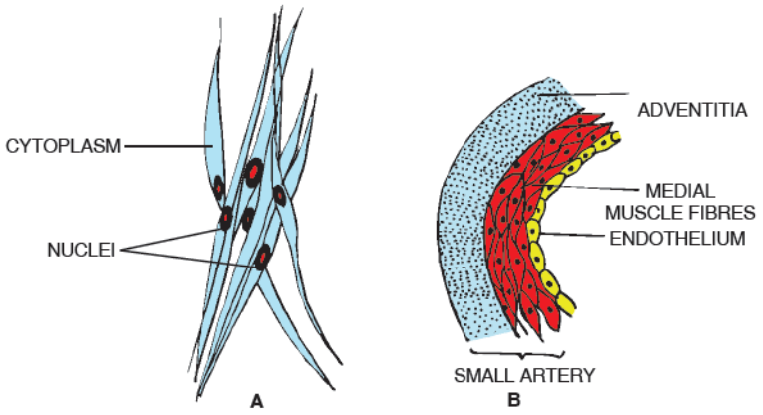


Fig. 24. A. Multi-unit smooth muscles. **B.** Single-unit smooth muscles.

C. CARDIAC MUSCLES (FIG. 25)

1. Position. These are found in the **myocardium** of the heart.

2. Structure

(a) **Similarities with striated muscle fibres.** Cardiac muscle fibres resemble striated muscles in being cylindrical; high vascularisation; having more mitochondria (as need more energy) and glycogen granules in the sarcoplasm; and having dark and light bands (**stratification**), and are covered by sarcolemma.

(*b*) **Similarities with smooth muscle fibres.** Cardiac muscles resemble smooth muscles in being uninucleate; smaller in size (85–100 µm long and 15 µm in diameter); in being involuntary.

(*c*) **Peculiar characters.** Cardiac muscles are **branched** cells and are joined end to end by flat, dense, zig-zag communication junctions, called **intercalated discs.** These allow rapid spread of calcium ions and excitation from one muscle fibre to next throughout the heart. The muscle fibres are interconnected by **oblique bridges** so forming a branching network. So these are arranged in a **syncitial manner**.

3. Mode of contraction. The cardiac muscles undergo **rhythmic contraction** and can initiate their own waves of excitation. These contract rapidly but **do not get fatigued** (called **fatigueless muscles**) so these work with same efficiency throughout life.

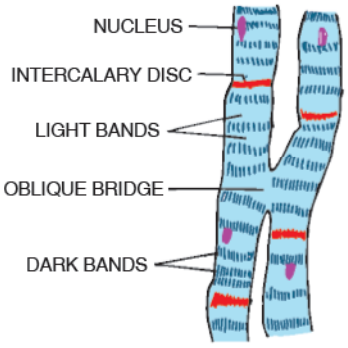


Fig. 25. Cardiac muscle fibres.

Table 11. Differences between Striated, Smooth and Cardiac muscles.

Characters	Striated muscles	Smooth muscles	Cardiac muscles
1. Position	Limbs, tongue, pharynx, beginning of oesophagus.	In wall of visceral organs and also in hair muscles.	Myocardium of heart.
2. Arrangement	In bundles.	As sheets in visceral organs.	Continuous network.
3. Size and shape	Long, cylindrical with blunt ends.	Short, spindle-shaped with pointed ends.	Short, cylindrical with flat ends.
4. Surface membrane	Sarcolemma.	Plasma membrane.	Sarcolemma.
5. Nucleus	Multinucleate nuclei peripheral.	Uninucleate. Nucleus central.	Uninucleate. Nucleus central.
6. Myofibrils	Presence of dark and light bands.	No bands.	Bands present.
7. Blood supply	Highly vascular.	Less vascular.	Highly vascular.
8. Mitochondria and glycogen granules	Numerous.	Less in number.	Numerous.
9. Innervation	From CNS.	From ANS.	Both CNS and ANS.
10. Branching	Unbranched	Unbranched.	Branched.
11. Mode of contraction	Contract rapidly for short period as soon get fatigued.	Contract slowly for long period as do not get fatigued.	Contract rapidly, rhythmically and never get fatigued.

LEARNING PLUS

- **Myoblasts :** Muscle-forming embryonic cells.
- Muscles of iris and ciliary body; and myoepithelial cells of salivary, mammary and sweat glands are **ectodermal** in origin.
- An average adult male is made up of 42% of skeletal muscles, while an average adult female is made up of 36% of skeletal muscles.
- **Epimysium :** A sheath of connective tissue covering the whole muscle.
- **Perimysium :** A sheath of connective tissue covering a bundle (fasciculus) of muscle fibres.
- **Endomysium :** A connective tissue sheath covering a muscle fibre.
- **Mesengial cells** are smooth muscle-like cells present in the glomeruli of the kidneys
- Cardiac muscles resemble the skeletal muscles in structure while are similar to smooth muscles in function.
- Cardiac muscles are also found in the wall of pulmonary veins and superior vena cava.

PRACTICE PROBLEMS – MUSCULAR TISSUE

16. Name two muscles of human body which are ectodermal in origin.
17. What are myofibrils?
18. Why do the muscle cells and nerve cells not have power of growth and regeneration?
19. Name three types of muscles found inside the human body.
20. List two structural differences between striated and unstriated muscle fibres.
21. What is structural and functional unit of a muscle fibre?
22. What do you mean by strification of muscle fibre?
23. List two differences between A-band and I-band.
24. List two structural adaptations in striated muscle fibres to draw more energy.
25. Why are striated muscles called skeletal muscles?
26. What do you mean by single-unit smooth muscles?
27. List two structural peculiarities of cardiac muscle fibres.
28. What is Z-line? Give its function.
29. What is sarcoplasmic reticulum? What is its function?
30. Why we shiver during winter months?

ANSWERS TO PRACTICE PROBLEMS

16. Ciliary muscles and iridial muscles of eye.
17. These are contractile proteinous threads, also called **sarcostyles**, present in cytoplasm of muscle fibres.
18. Because these are highly specialized for movements and locomotion; and nerve impulse conduction respectively.
19. Striated muscle fibres, smooth muscle fibres and cardiac muscle fibres.
20. (i) Striated muscle fibres are multinucleate and strified with A and I bands.
    (ii) Smooth muscle fibres are uninucleate and do not have A and I bands.
21. Sarcomere.
22. Muscle fibres having alternatively arranged A and I bands.
23. (i) A-band has a light H-zone at its centre and is formed of myosin and actin filaments.
    (ii) I-band has a dark Z-line at its centre and is formed of only actin filaments.
24. These are highly vascular, with large number of mitochondria and have large sized glycogen granules.
25. Because these are attached to the bones by tendons.
26. In this, smooth muscle fibres are joined by cytoplasmic bridges and contract simultaneously.
27. These have flat and zig-zag shaped ends called **intercalated discs** and are interconnected by oblique bridges so these **contract rhythmically.**
28. It is a dark-coloured membrane present in the centre of I-band. Actin filaments are attached to the Z-line.
29. It is an electron microscopic network of SER present in the sarcoplasm of muscle fibre. It releases Ca^{++} which starts biochemical reactions occuring during muscle - contraction.
30. In shivering, a large amount of energy involved in muscle contraction is changed into heat which helps to keep the body warm.

ADDITIONAL USEFUL INFORMATIONS ABOUT MUSCULAR TISSUE FOR COMPETITIVE EXAMINATIONS

- *Formation of muscular tissue during embryonic development is called **myogenesis**.*
- ***Myology :** Also called **sarcology** – deals with the study of muscles.*
- *There are about **639 types** of muscles in human body which form about half of body weight.*
- *Striated muscles form about **80% of soft tissues** of human body and **40% of body weight.***
- ***Hansen's or H–zone** of A–band is also called **Heller's line** or **Micellar** or **Mesogramme line.***
- ***Huxley and Verratti :** Described the ultrastructure of sarcomere.*
- *Voluntary muscles are also called **somatic muscles** or **biological motors** or **phasic muscles.***
- *Longest smooth muscles (of about 500 μm) are found in the wall of uterus of a pregnant female.*
- ***Intercalated discs** of cardiac muscle fibres are also called **booster rings** and have large number of calcium - channels.*
- *Largest muscle of human body is **Gluteus maximus** (Buttock muscle), while smallest muscle of human body is **Stapedius** muscle of middle ear.*
- *Longest muscle of human body is **Sartorius** while strongest muscles of human body are **jaw muscles.***
- ***Gastroenemius muscle :** Also called **calf muscle -** found on post-axial side of shank of leg.*
- ***Rigor mortis :** Rigidity of muscles after deaths first seen in jaw muscles; starts second hour after death.*
- ***Vigor mortis :** Rigidity of muscles due to deficiency of ATP in muscles.*
- *Skeletal muscles are of two types: – **Type-I (slow oxidative or slow twich) or Red muscles.** These are rich in blood capillaries and myoglobin. These sustain aerobic activity. **Type-II (fast twich) or White muscles.** These have less mitochondria and myoglobin. These sustain anaerobic or glycolytic activity.*

III. CONNECTIVE TISSUE

Basic structure. It is characterised by :

1. The cells are always **mesodermal** in origin.

2. There are large **intercellular spaces.**

3. Intercellular spaces are filled with large amount of extracellular materials formed of insoluble and structural **protein fibres** (e.g. collagen or elastin) lying in an amorphous, non-living, transparent ground substance called **matrix**. The matrix is mainly formed of **mucopolysaccharides** (*e.g.* hyaluronic acid) and structural **glycoproteins.** The matrix and fibres are usually secreted by the cells. The matrix can be liquid (e.g. blood) or rigid (e.g. bone).

4. The cells have **less power of division.**

5. It is the **most abundant** and widely distributed in the body of complex animals.

General functions. The connective tissues perform the following functions :

1. These **bind** different structures with one another *e.g.*, muscles with skin, muscles with bones etc.

2. These form **protective sheaths** around delicate organs such as spleen, kidneys, testes etc.

3. Skeletal connective tissue (bones and cartilages) forms **supporting framework.**

4. Vascular connective tissues help in the **transportation of materials** such as gases, food, wastes, hormones etc. inside the body.

5. Neutrophils of blood and lymph provide **protection against the bacterial infections** as these act as **phagocytes** and their activity is called **phagocytosis.**

6. Adipose connective tissue helps in **storage of fats.** It also forms shock-proof cushions around the kidneys, ovaries and eye balls.

7. Lymphocytes of blood secrete **antibodies** to provide immunity.

In general, connective tissue helps in **linking and supporting** other tissues/organs of the body.

Types. On the basis of **nature of matrix**, connective tissues are of **three types** and each type is further divided into subtypes (Table 12) :

A. CONNECTIVE TISSUE PROPER

It is characterised by **soft matrix**. It is divided into **five sub-types :**

1. Areolar (Loose Fibrous) connective tissue (Fig. 26)

Structure. It is characterised by transparent, gelatinous, highly vascular and sticky matrix which has a variety of cells and two types of fibres. The fibres are loosely arranged in a random manner hence called **loose fibrous connective tissue.**

(a) Cell types

(i) Fibroblasts (Fibrocytes). These are **most numerous** and **principal active** cell-type and are largest-sized, oval-shaped cells having branched cytoplasmic processes. These form the collagen and elastin protein fibres.

(ii) Macrophages (Histiocytes). These are large sized and amoeboid cells. These act as phagocytes and engulf bacteria, dead cells or other foreign material.

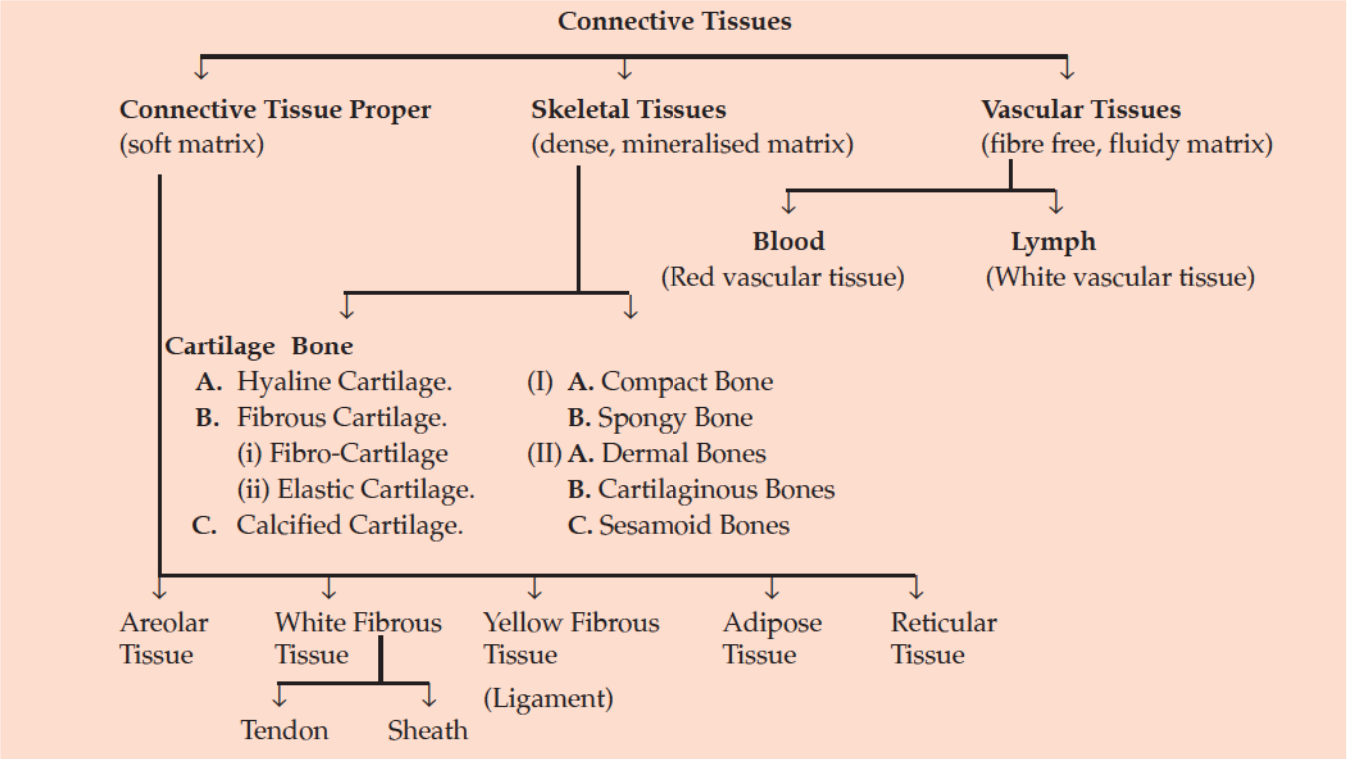
(iii) Mechanocytes (Mast cells). These are large rounded or oval cells. These **secrete the matrix** and also release heparin (anticoagulant), serotonin (vesoconstrictor) and histamine.

Besides these three main cell types, the matrix of areolar connective tissue may also have some other cell types such as lymphoid cells, pigment cells (chromatophores), undifferentiated mesenchyme cells and plasma or cart-wheel cells (produce anti-bodies).

(b) Fibre types. Areolar connective tissue has two types of protein-fibres :

(i) White or Collagen fibres. These are numerous, longer, thinner, unbranched, inelastic and wavy fibres which are found in bundles called **fascia**. These are chemically formed of **collagen protein.** These help to strengthen the structure and also help in the repair.

Table 12. Types of Connective Tissues.



(ii) Yellow or Elastic fibres. These are fewer in number, smaller in size, thicker, elastic, branched and straight fibres which occur singly. These are chemically formed of **elastin protein**. They give elasticity.

The spaces between the fibres are called **areolae,** so called **areolar connective tissue.**

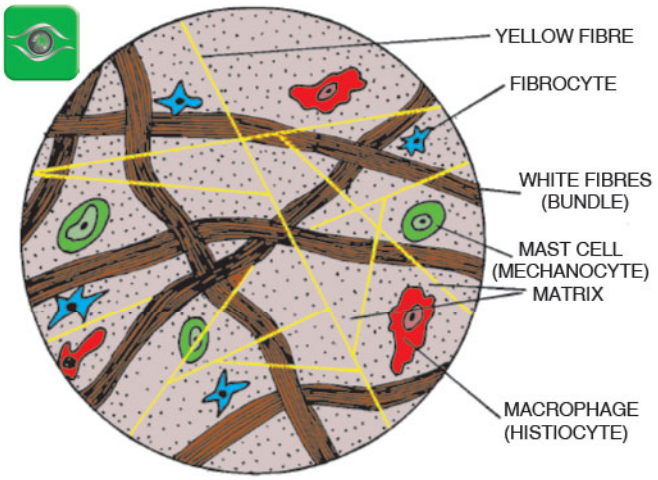


Fig. 26. Areolar tissue.

Position and Function. It is **most abundant type of connective tissue** and is widely distributed in the body. It is found beneath the skin, around visceral organs like stomach, intestine, skin, etc. and on the walls of blood vessels. It mainly acts as **binding tissue** and binds the skin with the muscles; mesenteries to the visceral organs; blood vessels and nerves with other structures of the body. **Heparin**, an anticoagulant, prevents the conversion of prothrombin into thrombin so prevents blood clotting. **Histamine** attracts the phagocytes to the site of infection so helps in healing process. **Serotonin** acts as vasoconstrictor so increases the blood pressure.

2. White fibrous connective tissue (Figs. 27 and 28)

Structure. It is a modified areolar connective tissue having small amount of matrix and large number of closely packed bundles of thick white fibres, so has great tensile strength.

Two forms of White fibrous tissue :

(a) Tendons (Fig. 27). In a tendon, the bundles of white fibres run parallel to one another so are very tough and inelastic. The fibroblasts lie in single rows between the bundles of white fibres. It is also called **dense regular connective tissue.**

Function. The tendons **join the muscles with the bones.** These also form **chordae tendinae.**

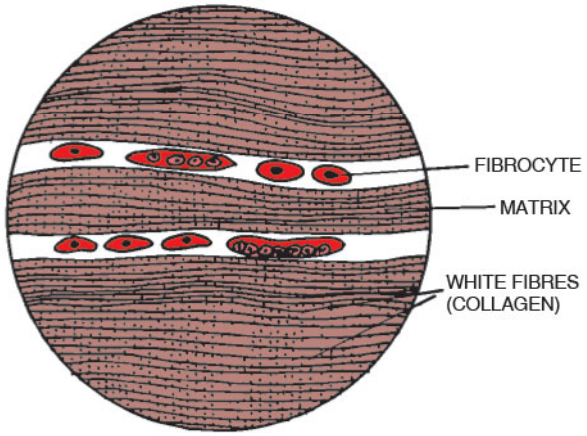


Fig. 27. White fibrous tissue (Tendon).

(b) Sheaths (Fig. 28). In a sheath, the bundles of white fibres lie in a criss-cross manner. The fibroblasts are scattered in the areolae. It is also called **dense irregular connective tissue.**

Position and Functions. The sheaths form protective covers such as **pericardium** (around heart), **duramater** (around brain), **perichondrium** (around the cartilage), **periosteum** (around bone), **sclerotic** (around eye) **tunica adventitia or externa** (outer coat of blood vessels) and **capsule** of kidneys, testes and spleen. It also joins the skull bones to form **sutures.**

Table 13. Differences between White and Yellow fibres.

Characters	White fibres	Yellow fibres
1. Appearance	These are wavy, unbranched, inelastic but flexible fibres.	These are straight, branched and elastic fibres.
2. Arrangement	These occur in bundles called fasciculi.	These occur singly.
3. Chemistry	Formed of **collagen** protein.	Formed of **elastin** protein.
4. Function	These give **tensile strength**.	These give **elasticity**.
5. Boiling effect	Collagen changes to gelatin protein.	Resistant to boiling.

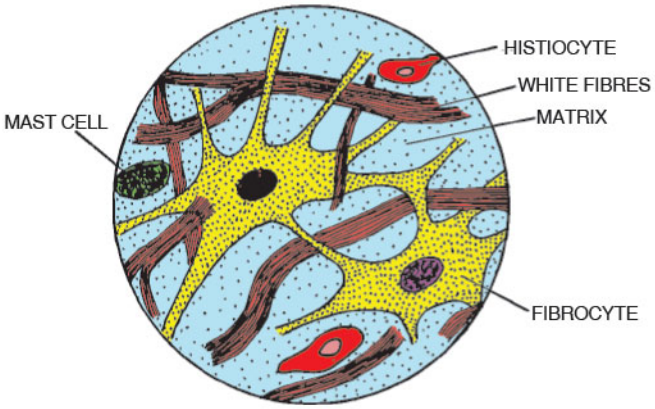


Fig. 28. White fibrous tissue (Sheath).

3. Yellow fibrous connective tissue (Fig. 29).

Structure. It is a modified areolar connective tissue :

(a) The matrix is with numerous and closely packed thick yellow or elastin fibres.

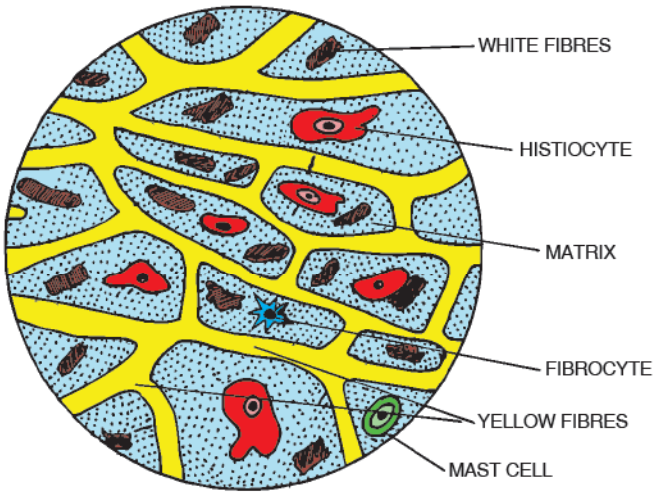


Fig. 29. Yellow fibrous connective tissue.

(b) Fibroblasts lie irregularly in the matrix.

(c) It is elastic and flexible.

Position and Function. It forms sheets in ligaments, the wall of blood vessels, lungs and bronchioles. **Ligaments join bones at the joints.** It also helps in recovery of blood vessels, lungs etc.

4. Adipose tissue (Fig. 30)

Structure. It is a modified areolar tissue :

(a) The matrix is packed with large spherical **fat cells** or **adipocytes**.

(b) Each fat cell has either a large fat globule (called **monolocular** in white or yellow fat) or a number of small fat droplets in the middle (called **polylocular** in brown adipose tissue) so that the nucleus is excentric.

(c) The matrix also has a few small sized bundles of white fibres and macrophages.

Position and Function. It is found beneath the skin (**panniculus adiposus**); around certain organs like kidneys, eyes, heart etc; and in the mesenteries and bone marrow. Adipose tissue acts as a **fat storing tissue** *e.g.* fat bodies in frog. It prevents the loss of body heat and helps in **homeothermy.** It acts as a **shock absorber** around kidneys (**Renal fat**) and eye balls.

5. Reticular tissue (Fig. 31)

Structure. It is a modified form of areolar connective.

(a) The **matrix is fluidy** in nature.

(b) The matrix contains large number of stellate-shaped **reticular cells**.

(c) The protoplasmic processes of adjoining cells are interconnected to form a close network.

(d) The reticular cells secrete **reticular fibres** formed of a protein called **reticulin** (modified collagen).

Position and Function. Reticular tissue is found in **spleen, thymus, tonsils, lymph nodes, liver, bone-marrow, lamina propria** of mucosa of stomach and intestine. The reticular cells act as **phagocytes.**

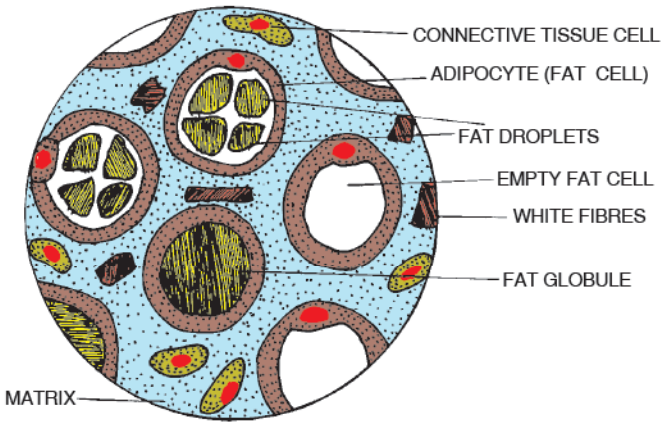


Fig. 30. Adipose tissue.

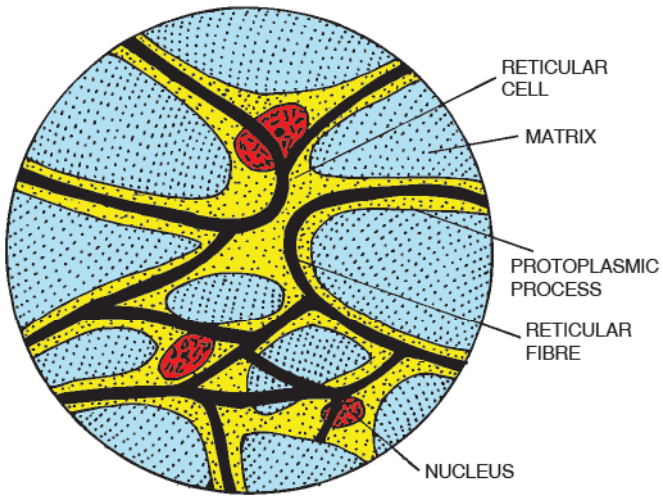


Fig. 31. Reticular connective tissue.

Table 14. Differences between Dense regular and Dense irregular tissue.

Characters	Dense regular tissue	Dense irregular tissue
1. Arrangement of bundles of white fibres	Run parallel to one another.	Lie in a criss – cross manner.
2. Arrangement of fibroblasts	Lie in rows between the bundles of white fibres.	Scattered in the areolae.
3. Structures formed	Tendons.	Periosteum, perichondrium, duramater, pericardium, capsules of kidneys and testes.
4. Function	Join muscles to bone.	Protection.

Table 15. Differences between Tendons and Ligaments.

Characters	Tendons	Ligaments
1. Structure	Formed of **white fibrous** connective tissue.	Formed of **yellow fibrous** tissue.
2. Arrangement of fibroblasts	In rows between the bundles of white fibres.	Scattered in matrix.
3. Nature	Tough and non-flexible.	Elastic and flexible.
4. Function	Join muscles to bones.	Join bones together.

R U CURIOUS

- Connective tissues are of three types :
  – **Loose connective tissues** e.g. Areolar and adipose tissue.
  – **Dense connective tissues** e.g. Tendon and ligament.
  – **Specialized connective tissues** e.g. Cartilage, bones, blood and lymph.
- **Areolar C.T.** is considered **prototypic** or basic type of connective tissue while other types of connective tissue are considered as its modifications in which one component or another predominate over the others.
- **Hump** of camel and **thick tail** of Merino sheep are formed of adipose tissue.
- **Blubber :** Thick layer of adipose tissue beneath the skin of whale and polar bear.
- **Leather** is derived from the dermis of skin having abundant white fibres after chemical treatment called **tanning.**

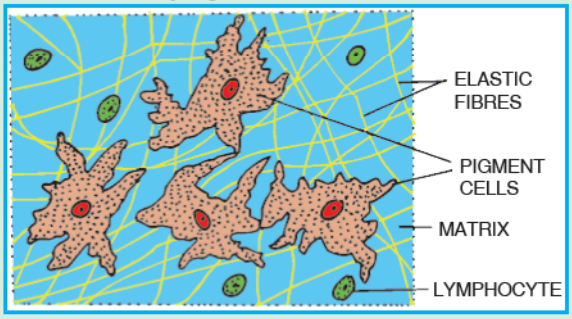


Fig. 32. Pigmented connective tissue.

- **Pigmented connective tissue (Fig. 32)** is found in choroid, ciliary body and iris of eye. Its matrix has very large number of irregular **chromatophores** (pigment cells) which contain melanin granules produced by special cells called **melanocytes** but later engulfed by pigment cells by phagocytosis. It gives colour to choroid, ciliary body and iris.

PRACTICE PROBLEMS – CONNECTIVE TISSUE PROPER

31. On the basis of matrix, connective tissues are of three types. Name them.
32. Name five types of connective tissue proper.
33. Name different types of cells found in the matrix of areolar connective tissue. Give their function.
34. List two differences between white fibres and yellow fibres.
35. Why is areolar connective tissue called loose fibrous connective tissue?
36. Define tendon. Give its function.
37. What is ligament? What is its function?
38. How do white adipose tissue and brown adipose tissue differ from each other?
39. What are reticular cells? Give their function.
40. What is blubber? Give its function.

ANSWERS TO PRACTICE PROBLEMS

31. (i) Connective tissue proper, (ii) Skeletal connective tissue, (iii) Vascular connective tissue.
32. (i) Areolar connective tissue, (ii) White fibrous connective tissue, (iii) Yellow fibrous connective tissue, (iv) Adipose connective tissue and (v) Reticular connective tissue.
33. (i) Fibroblasts secrete the fibres.
    (ii) Mast cells secrete connective tissue matrix, heparin, histamine and serotonin.
    (iii) Histiocytes act as phagocytes and eat upon microbes.
    (iv) Plasma cells secrete antibodies.
34. (i) White fibres are formed of collagen protein, arranged in bundles and give rigidity.
    (ii) Yellow fibres are formed of elastin protein, present singly and provide elasticity.
35. In the matrix of areolar connective tissue, fibers are arranged loosely.
36. Tendon is a band of white fibres which joins muscles to bone.
37. Ligament is a band of yellow fibres which joins bone to bone.
38. White adipose tissue of blubber of whale or hump of camel is formed of **monolocular adipocytes**, while brown adipose tissue of subcutaneus zone of skin is formed of **polylocular adipocytes.**
39. These are star-shaped phagocytic cells of spleen, thymus, tonsils, etc. and eat upon the mirobes.
40. It is a thick layer of white adipose connective tissue present beneath the skin of whale. It conserves the body heat and helps in homeothermy.

ADDITIONAL USEFUL INFORMATIONS ABOUT CONNECTIVE TISSUE PROPER FOR COMPETITIVE EXAMINATIONS

- *Connective tissue forms **30%** of body weight.*
- ***Hertwig** (1883) : Called the connective tissue as **mesenchyme.***
- ***Areolar connective tissue** is simplest connective tissue. It is also called **loose fibrous** or **spongy connective tissue.***
- ***Histiocytes** are also called **clasmatocytes** and are modified monocytes of blood and act as **scavengers.** These form **'mopping up'** operations. These are chief phagocytes of the body. These are involved in phagocytosis (first reported by **Metchnikoff** – 1882).*
- ***Dust cells :** Histiocytes of lung septa.*
- ***Mast cells** are modified basophils of blood.*
- *On boiling, collagen of white fibres changes to **gelatin protein,** while elastin is resistant to boiling.*
- ***Tendons** join the muscles to bones, while **ligaments** join bone to bone.*
- ***Sprain :** Excessive pulling of ligaments.*
- ***Mucoid tissue :** An embryoid tissue found in **umblical cord.** Also called **Wharton's jelly.** It is most primitive type of tissue. Found in **viterous humour** of eye and **cock's comb.***
- ***Brown fats :** Also called **hibernating gland** as found in hibernating mammals e.g. bats and squirrels, Kangaroo rats and newly born human babies. Each brown fat cell is **polylocular** and contains iron-containing cytochrome pigments. These produce more energy than white fats (monolocular) because these have an oxidation power 20 times more than that of yellow fat as brown fat cells have more mitochondria. Brown colour is due to cytochrome oxidase enzyme.*
- ***Collagen :** Most abundant protein of body and forms 40% of total body proteins. In old age, rigidity of collagen decreases which causes wrinkles in skin.*
- ***Mummies** of earlier period are still preserved due to well preserved elastic fibres.*
- *All the cells of connective tissue develop during embryonic development from the undifferentiated stellate cells called **mesenchyme (stem) cells.***

B. SKELETAL TISSUE

Skeletal tissue is characterised by dense and **mineralised matrix**.

General functions

1. These form **supporting framework** of body.

2. These provide hard surfaces for the **attachment of the tendons** of the muscles.

3. These form **endoskeleton** of the vertebrates.

4. These **protect** the vital organs of body like **brain, heart, lungs** etc.

Two types of Skeletal tissue :

1. Cartilage and 2. Bone

1. Cartilage

General structure (Hyaline cartilage) (Fig. 33). A cartilage is a solid, semi-rigid and flexible tissue. It is basically formed of **three parts:**

(a) Chondroblasts (*chondro*= cartilage). These are oval-shaped cartilage cells which are generally present in the groups of 2-4 cells. Each cell lies in a fluid-filled space called **lacuna**. The chondroblasts in lacunae are smaller and lie more closer near the periphery.

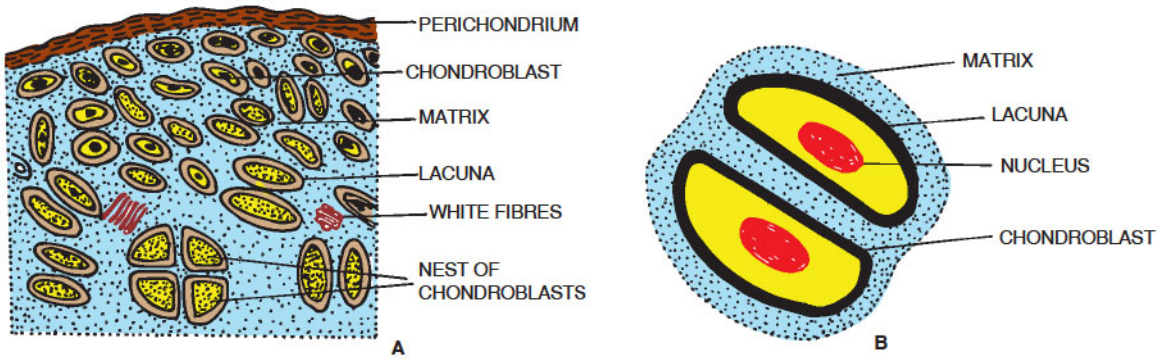


Fig. 33. Hyaline cartilage. **A.** T.S. of Hyaline cartilage. **B.** Chondroblasts in lacunae.

(b) Matrix. Matrix of the cartilage is formed of **chondromucoid,** a **proteoglycan** formed of **chondroitin sulphate** and **albuminoid (Chondrin** protein). It is without blood supply. The matrix of cartilage is flexible and resists compression. The matrix is externally covered by a dense white fibrous sheath, **perichondrium,** which contains blood vessels to supply nutrition to the chondrocytes by diffusion. So the growth of the cartilage is always from the periphery **(unidirectional).**

(c) Fibres. Matrix of cartilage also has a few bundles of small sized collagen fibres.

General function. Cartilages help to absorb mechanical shocks.

Types of cartilages. On the basis of the **composition of the matrix**, the cartilages are classified into following **three types** :

(a) Hyaline cartilage (Gristle) (Fig. 33). Its matrix is transparent, homogenous and pearly-white or bluish-green in colour. It gives glass-like appearance.

It is slightly elastic. It is present at the end of **limb bones** (called **hyalin caps** or **articular cartilages**) and the **sternum**; in the **hyoid apparatus, nasal septum, larynx, trachea, sternal parts of ribs** (called **costal cartilages**) and **bronchi** in adult. It also forms skeleton of adult cartilage fishes like rays and sharks.

(b) Fibrous cartilage. In this, the matrix of the cartilage is with large number of fibres. On the basis of **type of fibres** present, it is of **two types** (Table 16) :

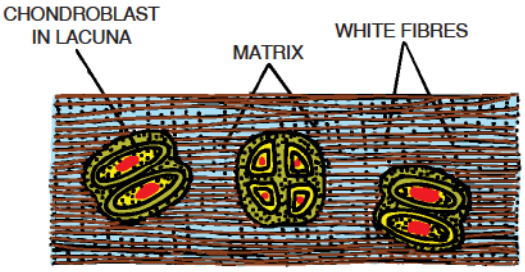


Fig. 34. T.S. Fibro-cartilage.

Table 16. Differences between Fibro-cartilage and Elastic-cartilage.

Characters	Fibro-cartilage (Fig. 34)	Elastic-cartilage (Fig. 35)
1. Type of fibres	Contains large number of collagen fibres.	Contains large number of elastic fibres.
2. Nature	Toughest, strong and inflexible.	Elastic and flexible.
3. Occurrence	Intervertebral discs and pubic symphysis.	Epiglottis, pinna, Eustachian tube etc.

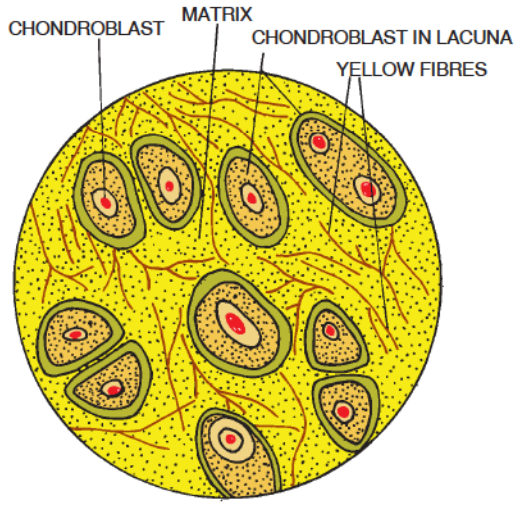


Fig. 35. T.S. Elastic cartilage.

(c) Calcified cartilage. It is a special type of cartilage, in which the matrix is deposited with calcium salts. It is very hard, inelastic and brittle. It is found in the **suprascapula** of pectoral girdle; **pre-coracoid** and **epicoracoid** of pectoral girdle of a lizard and vertebrae of sharks. It is mainly **protective** in function *e.g.*, suprascapula of pectoral girdle of frog protects the heart and lungs.

2. Bone (Osseous tissue) (Fig. 36)

General structure. Bone forms the major part of the endoskeleton of bony fishes and tetrapods. It is solid, rigid, **inflexible, hardest and strongest** connective tissue. It is characterised by :

(a) The matrix of bones (called **osteoid matrix**) is formed of two types of matter — **organic (animal) matter** (35 – 40%) and **inorganic (mineral) matter** (60 – 65%).

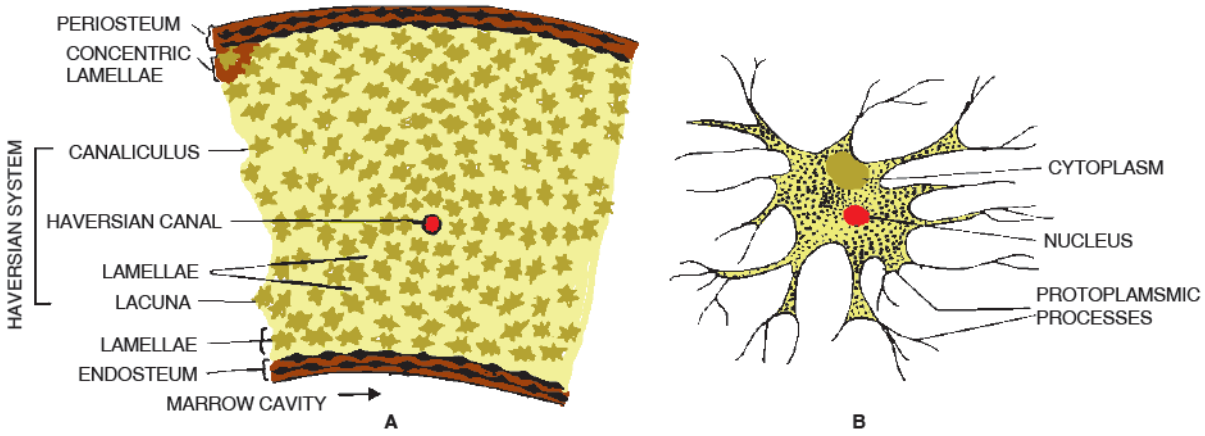


Fig. 36. A. T.S. Dry bone of mammal (A part). **B.** An osteocyte.

(b) Organic matter is formed of a protein, the **ossein**, secreted by the osteocytes.

(c) Inorganic matter is formed of phosphates, sulphates, carbonates and fluorides of calcium and magnesium. Most abundant mineral is **calcium phosphate**. These minerals provide hardness to the bone.

(d) With advancing age, the inorganic matter increases so the bones in old age are brittle.

(e) Long bones such as humerus, femur etc. are hollow and each has a central cavity called **marrow** or **medullary cavity.** But the small bones are solid.

(f) Marrow cavity is filled with a soft and vascular fatty tissue called **bone-marrow** (also called **myeloid tissue**). The bone marrow is of two types—**red marrow** and **yellow marrow**. The red bone marrow is highly vascular reticular tissue and **forms erythrocytes and granular leucocytes.** The yellow bone marrow is mainly involved with the storage of fat. It also forms blood corpuscles only at the time of emergency.

(g) A bone is externally covered by a thick, white fibrous sheath called **periosteum.** Marrow cavity is lined by a thin sheath called **endosteum**. Periosteum provides surface for the attachment of tendons and muscles.

(h) Running in the wall of bone, there are a number of longitudinal canals, the **Haversian canals**, which are interconnected by small transverse and oblique canals called **Volkmann's canals**. These canals contain branches of blood vessels, lymph vessels and nerves in areolar tissue which supply nutrition and oxygen to and receive metabolic wastes from the osteocytes.

(i) The matrix of the bone is arranged mainly in the form of concentric rings (about 6-15 in number) called **lamellae** around each Haversian canal and are called **Haversian lamellae.** Just inner to periosteum and outer to endosteum, a few layers of lamellae run parallel to the surface and are called **circumferential lamellae.**

(j) The lamellae are separated by numerous small spaces called **lacunae**. Each lacuna gives branched processes, **canaliculi**, which join the canaliculi of adjoining lacunae to form a network.

(k) Each lacuna is occupied by an irregular bone cell, **osteocyte** (Fig. 36B). It gives branched protoplasmic processes into the bone canaliculi. The protoplasmic processes of adjoining cells unite with one another to form a protoplasmic network throughout the matrix.

(l) A Haversian canal with its lamellae, lacunae and canaliculi forms a **Haversian system** or **osteon**.

(m) The spaces between the Haversian systems are filled by **interstitial lamellae.**

(n) Present inner to periosteum and outer to endosteum, there are cuboidal cells called **osteoblasts**. Inner layer is called **germinative** or **cambium** while outer layer is called **exosteum** These undergo mitosis and produce the bone cells, **osteocytes**, which secrete ossein in the matrix. Thus, the **growth of the bones is bi-directional**.

Table 17. Differences between Red bone marrow and Yellow bone marrow.

Characters	Red bone marrow	Yellow bone marrow
1. **Position**	Found in epiphyses of the bones.	Found in the shaft of long bones.
2. **Blood supply**	More vascular.	Less vascular.
3. **Function**	Produces erythrocytes and granular leucocytes.	Stores fats.

Table 18. Differences between Cartilage and Bone.

Characters	Cartilage	Bone
1. Nature of matrix	Tough and pliable.	Tough and non-pliable.
2. Chemistry of matrix	Formed of only organic matter called **chondrin** protein which is deposited with minerals only in calcified cartilage.	Formed of both organic and inorganic matter. Organic matter formed of **ossein** protein while inorganic matter mainly formed of calcium phosphate.
3. Nature of cell	Only one type of cells—**chondroblasts** which are present in the groups of 2 or 4. Chondroblasts have no protoplasmic processes.	Two types of cells in the bone—**osteoblasts** and **osteocytes**. The cells never found in groups. Osteocytes give protoplasmic pro-cesses.
4. Nature of lacunae	Lacunae are without canaliculi.	Each lacuna gives branched processes, **canaliculi.**
5. Growth	Growth is **unidirectional** *i.e.*, from periphery.	**Bidirectional** growth.
6. Canal system	There are no Haversian and Volkmann's canals.	Haversian and Volkmann's canals are present.
7. Arrangement of matrix	Not arranged in lamellae.	Arranged in lamellae.
8. Blood supply	Matrix is non-vascular.	Matrix is vascular.
9. Cavity	Cartilage is always solid.	Long bones are hollow. Each has a marrow cavity.

Types of Bones:

I. On the basis of their texture: The bones are of **two types : A. Spongy bones** and **B. Compact bones** (Table 19) :

Table 19. Differences between Spongy (cancellous) bone and Compact bone (Fig. 37).

Character	Spongy bone	Compact bone
1. Arrangement of lamellae	There is no regular Haversian system so have spongy texture.	Have regular Haversian system.
2. Occurrence	In skull bones, vertebrae, ribs and **epiphyses** of long bones.	In the shaft (**diaphysis**) of long bones.
3. Marrow cavity	Absent.	Present.
4. Type of bone marrow	Red marrow in the spaces between lamellae.	Yellow marrow in marrow cavity.
5. Function	Marrow forms RBCs and granular WBCs.	Marrow stores fats.

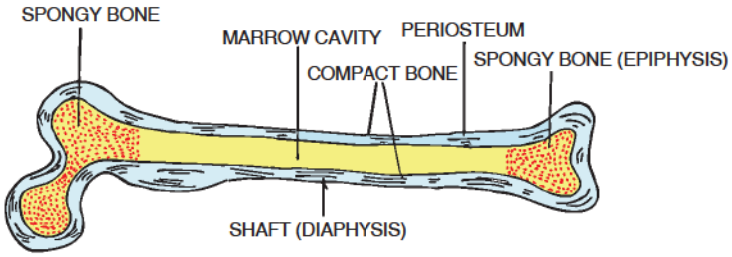


Fig. 37. L.S. Femur to show spongy and compact bones.

II. On the basis of treatment : Bones are of two types: **A. Dried bone** and **B. Decalcified bone** (Table 20) :

Table 20. Differences between Dried bone and Decalacified bone.

Character	Dried bone	Decalcified bone
1. Type of treatment	Subjected to high temperature.	Subjected to dilute solution of HCl.
2. Nature of matter left	With only mineral matter.	With only organic matter.
3. Marrow cavity	Empty.	With bone-marrow.
4. Fate of cells	Periosteum, endosteum, osteoblasts and osteocytes are absent being killed by high temperature.	Periosteum, endosteum, osteoblasts and osteocytes all are present.
5. Lacunae	Lacunae present.	Lacunae absent.

2. On the basis of origin of bone : The bones are classified into **three categories** (Table 21) :

Table 21. Differences between Cartilaginous, Dermal and Sesamoid bones.

Cartilaginous or Replacing (Endochondral) bone	Dermal (Intramembranous) bone	Sesamoid bone
1. These are formed by ossification directly on the cartilages.	1. These are formed by ossification in the dermis of the skin.	1. These are formed by ossification at the joints of the bones or on the tendon and ligament.
2. These are elongated and hard bones.	2. These are membrane-like bones.	2. These are small sized, disc-like bones.
3. *Example* : **Vertebrae, Girdle bones, Humerus, Femur** and **Fibula**.	3. *Example* : **Skull bones, Phalanges, Clavicles.**	3. *Example* : **Patella bone** (knee cap).

REMEMBER

- Cartilages form **soft skeletal tissue.** These form whole of endoskeleton of cartilage fishes.
- **Sharpey's fibres :** These are bundles of white (collagen) fibres which penetrate the bone matrix and help in firm connection between the bones.
- Most of embryonic skeleton is formed of hyaline cartilages.
- Fibrocartilage is also called **white fibrous cartilage,** while elastic cartilage is also called **yellow fibrous cartilage**.
- Intervertebral discs act as **shock absorber** between the vertebrae, while pubic symphysis helps in **child birth (parturition)**
- There is **no perichondrium** in both types of fibrous cartilages.
- Yellow fibrous cartilage provides **recoiling power** to the organs.

PRACTICE PROBLEMS – SKELETAL CONNECTIVE TISSUE

41. List two basic functions of skeletal connective tissue.
42. What is nature of matrix of cartilage?
43. Which is the most common type of cartilage? Give its basic function.
44. What are chondroblasts?
45. Name two types of cells found in a bone.
46. Which is the hardest cartilage? Give one example and its function.
47. Why is the fibro-cartilage toughest and hardest?
48. What is the nature of matrix of bone?
49. What is bone narrow? Give its function.
50. Name two types of canals present inside the body. What is their function?
51. What is sesamoid bone? Give one example.

ANSWERS TO PRACTICE PROBLEMS

41. (i) It forms supporting framework of body.
(ii) It protects important organs (*e.g.* brain, heart, lungs, etc.).
42. It is glycoproteinous and is formed of chondroitin sulphate (a polysaccharide) and chondrin protein.
43. Hyaline cartilage is most common type of cartilage. It acts as mechanical shock absorber.
44. There are oval-shaped cells which secrete matrix of cartilage and are present in groups of 2 or 4.
45. Osteoblasts and osteocytes.
46. Calcified cartilage e. g. suprascapula of pectoral girdle of frog which protects the heart and lungs as frog does not have ribs.
47. In fibro-cartilage, matrix is with large number of thick white fibres.
48. Matrix of bone is formed of both inorganic or mineral matter (e.g. mainly **calcium phosphate**) and organic or animal matter (e.g. **ossein protein).**
49. Bone marrow is a vascular adipose tissue present in the marrow cavity of the bones. Red bone marrow forms RBCs and granular WBCs while yellow bone marrow stores the fats.
50. Haversian canals interconnected by Volkmann's canals. These canals have blood capillaries to provide nutrition and oxygen to and receive metabolic wastes from the bone cells.
51. Sesamoid bone is a disc-like bone formed at the joint of two bones to strengthen the joint e.g. **Patella bone** (knee cap).

ADDITIONAL USEFUL INFORMATIONS ABOUT SKELETAL CONNECTIVE TISSUE FOR COMPETITIVE EXAMINATIONS

- *Chondrology : Study of cartilages.*
- *Chondrogenesis : Process of formation of cartilages.*
- *Gristle : Another term for hyaline cartilage which is most primitive type and most abundant type.*
- *Young and more active cartilage cells are called chondroblasts, while mature and less active cartilage cells are called chondrocytes.*
- *Osteology : Study of bones.*
- *Osteogenesis (ossification) : Formation of bones.*
- *Red bone marrow is present in spongy part (epiphyses) of bones, while yellow bone marrow is present in the shaft (diaphyses).*
- *Bone forming cells are called osteoblasts, while bone dissolving cells are called osteoclasts (contain lysosomes).*
- *Bone resorption : Destruction of bone matrix by osteoclasts.*
- *Spongy bone is also called Cancellous or Tubecular bone, while compact bone is also called periosteal bones.*
- *Calcination : Process of burning of bone till it becomes white.*
- *As the matrix of cartilage is non-vascular, so an injured cartilage takes long period to heal.*
- *Sesamoid bones e.g. cotyloid of pelvic girdle; Fabella bone.*
- *Osteoid is the uncalcified matrix of bone.*
- *Strongest cartilage is Fibro cartilage due to collagen fibres.*
- *Osteoblasts are called bone forming cells, while osteocytes are called bone maintaining cells.*
- *Visceral bones : Bones present in certain visceral organs e.g.*
  - *Os penis : Bone found in penis of rodents, bats, carnivores, whales, etc.*
  - *Os cordis : Bone found in the heart of some ruminants like deer.*
  - *Os clitoris : Bone found in clitoris of many carnivores.*

C. VASCULAR TISSUE

It is a fluidy connective tissue which differs from connective tissue proper in following characters :

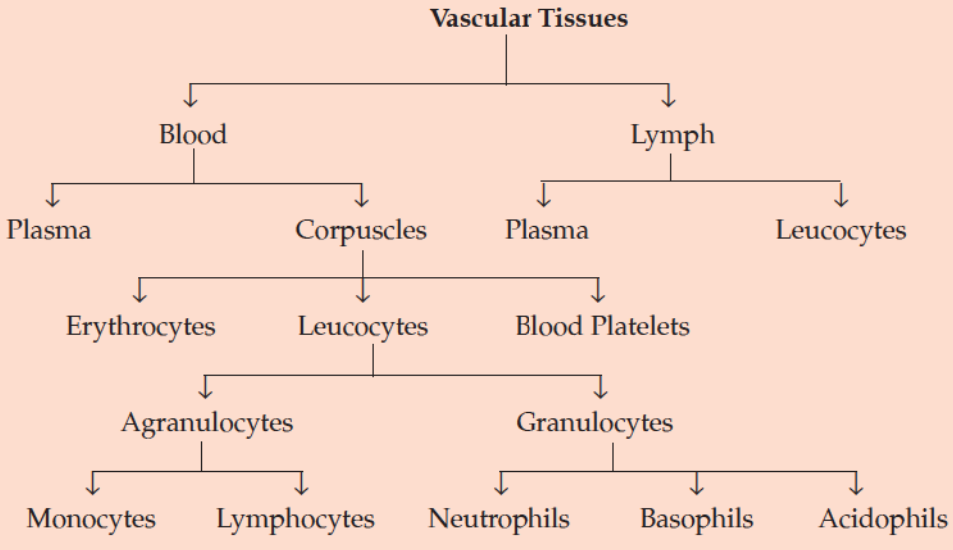
1. The matrix is **fluidy, mobile and fibre free.**
2. The matrix is **not secreted by the cells.**
3. The cells have **no power of division.**

It circulates in the body and is responsible for the **transportation** of materials from one place to another within the body. It also plays an important role in the **defence-mechanism** of the body.

TYPES OF VASCULAR TISSUES

Vascular tissues are of 2 types—**blood** and **lymph**. (Table 22):

Table 22. Composition of Vascular Tissues.



1. BLOOD

Physical characters. The blood is **red, mobile, vascular and softest connective tissue**. It is opaque, **sticky,** viscous and slightly **heavier than water** (specific gravity = 1.057 in males). It is **slightly alkaline** in nature **(Average pH = 7.4).** The oxygenated blood is **bright red,** while the deoxygenated blood is **purple.**

Percentage. Blood forms about **6-10%** (Average **7-8%**) of the body weight and about 30-35% of the ECF. The volume of blood in an adult person is about **6.8 litres**.

Composition. The blood is formed of **two parts** :

(a) Plasma. It is a straw-coloured non-living fluid which forms about **55-60%** of the blood volume.

Composition. Chemically, the plasma is composed of—

Water = 90-92%

Inorganic salts = 1-2%

Plasma proteins = 6-8%

Other organic compounds = 1-2%

Inorganic salts are chlorides, carbonates, bicarbonates, sulphates and phosphates of sodium, potassium, calcium, magnesium, iron etc. Plasma proteins mainly include albumins (4.0%), globulins (2.5%), fibrinogen (0.3%), properdin and prothrombin (0.03%). Other organic compounds include :

— food materials like glucose, amino acids, fatty acids, vitamins etc.

— wastes like urea, uric acid, creatinine etc.

— enzymes, hormones, antibodies, anticoagulants, gases (O_2, CO_2) etc.

Glucose is the main nutritive material carried by blood while urea is the main nitrogenous waste in blood.

Functions of Plasma. The plasma helps in the following functions:

(i) **Transportation.** Plasma transports simple **food components** like glucose, amino acids, fatty acids, vitamins etc. from the intestine and liver to other body parts; **1-3%** O_2 from the lungs to the body tissues for oxidation of food; **7%** CO_2 from the cells to the lungs for expiration; **metabolic wastes** like urea, uric acid etc. from body tissues to the kidneys for their excretion; **hormones** from the endocrine glands to their target organs; **lactic acid** from the muscles to the liver to change it partly into glycogen. So blood plasma helps in **nutrition, excretion, respiration** and **homeostasis.**

(ii) **Homeothermy.** Plasma helps in **homeothermy** by transporting heat.

(iii) **pH constancy**. Certain minerals (*e.g.* Sodium bicarbonates) and proteins of plasma act as **acid-base buffers** and help in keeping a constant pH of blood.

(iv) **Blood clotting.** Prothrombin and fibrinogen, blood proteins, help in blood clotting at the injury.

(v) **Immunity.** γ-globulin proteins of plasma act as immuno-globulins which provide resistance against a number of diseases.

(vi) **Osmotic balance.** The albumins of blood-plasma can hold water so are responsible for osmotic balance of blood.

(vii) **As a middle man.** The plasma forms the **tissue fluid** which keeps the tissues moist and acts as **middle man** between the blood and the body cells.

(*viii*) **Properdin** destroys certain bacteria and neutralises certain viruses.

(*ix*) **Erythropoiesis. Erythropoitin** (hormone secreted by kidneys) stimulates the RBC formation.

(*x*) **Transportation of minerals. Transferrin** globulin carries the iron while **ceruloplasmin** globulin carries copper.

(b) Blood corpuscles (Formed elements) (Figs. 38-43). The blood corpuscles are the cells which float freely in the plasma. These form **40-45%** of blood-plasma.

Types of Blood cells (Formed elements). Blood is with **three types** of blood corpuscles :

(i) Erythrocytes or Red blood corpuscles (R.B.Cs.)

Shape. In all vertebrates except mammals, the erythrocytes are oval, biconvex and nucleated **(Fig. 38).** In mammals except camel and llama, the mature erythrocytes are circular, biconcave and non-nucleated. The biconcave shape increases the surface area to volume ratio and the absence of nucleus increases the haemoglobin contents and also increases the motility.

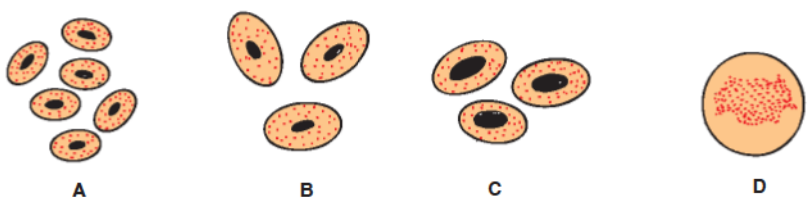


Fig. 38. Erythrocytes in different vertebrates. **A.** Fish. **B.** Amphibian. **C.** Bird. **D.** Mammal.

Size. A human RBC **(Fig. 39)** is about 7-8 μm in diameter.

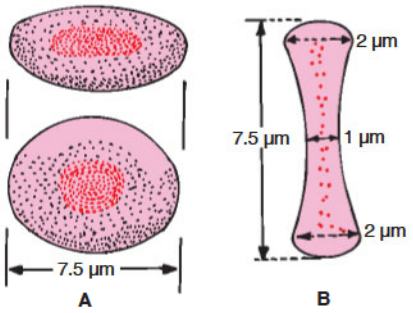


Fig. 39. Human erythrocyte.

Number. The RBCs are much more in number than the WBCs. The total number of RBCs per μL is called **RBC count.** Normal RBC count is slightly lower in a woman than a man. Normal RBC count in an adult human male is **5—5.5 million per cubic millimetre** of blood ($5.0—5.5 \times 10^{12}$/litre of blood; Average **5.5 ± 1.0 million/mm³**) while it is **4.5—5.0 million per cubic millimetre** of blood ($4.5—5.0 \times 10^{12}$/litre of blood) in a normal adult woman. The instrument used to determine RBC count is **haemocytometer.** Two important factors which increase the RBC count are : physiological state (more during exercise due to increased demand of oxygen) and high altitudes (low oxygen concentration in the air). When RBC count decreases then it is called **anaemia** while RBC count increases much more than the normal level in **polycythemia**.

Colour. An RBC appears yellow when seen singly but these appear red when in bulk due to presence of a iron containing pigment **haemoglobin.**

Structure. A human RBC is bounded by an elastic and semipermeable plasma-membrane which enables it to squeeze through narrow capillaries. The mature mammalian RBC is also characterised by absence of nucleus, mitochondria (as shown by **glycolytic pathway**) and endoplasmic reticulum so there is low consumption of oxygen by itself and is primarily concerned with the transport of oxygen.

Haemoglobin is a purple-coloured conjugated protein and is formed of **4 haeme groups** and a protein called **globin**. Each haeme group contains an iron-containing porphyrin ring formed of 4 pyrrole rings. Globin is formed of 4 polypeptide chains—2α and 2β chains. One RBC has about 280 million haemoglobin molecules.

Amount of haemoglobin per 100 ml of blood is called **haemoglobin count** and is measured by an instrument called **haemometer.** Average Hb-count for healthy individual is 12 – 16 gm/decilitre of blood.

Life Span. Due to absence of nucleus, the RBCs are short lived. The old and worn out erythrocytes are destroyed by the reticuloendothelial cells of liver, spleen and bone marrow. The process is called **haemolysis**. The haemoglobin is changed into **haemosiderin** and the bile pigments **bilirubin** and **biliverdin**. The bone marrow can use most of the iron again in the formation of new haemoglobin while the bile pigments are expelled along with the faecal matter. RBCs are haemolysed at the rate of about 2.5 million per second but are also formed at the same rate.

Average life span of human RBC is **115 -120 days**.

Formation. The formation of red blood cells is called **erythropoeisis** while the organs forming red blood cells are called **erythropoeitic organs.** It occurs in the presence of a glycoproteinous hormone, the **erythropoeitin** formed by the kidney. In the developing foetus, the haemopoeitic tissues are liver and spleen while after the birth, RBCs are mainly produced in the bone marrow of the long bones. The haemopoeisis is also controlled by iron and proteins while the maturation of RBC is controlled by folic acid and vitamin B_{12} (Cobalamine). Therefore, deficiency of these substances in the blood causes **anaemia**. The excess of erythrocytes is stored in the spleen which acts as a **blood bank** of the body. Spleen also acts as "**graveyard**" of RBCs.

Functions

* Haemoglobin carries about 97-99 per cent of oxygen from the lungs to body tissues as **oxyhaemoglobin.** One molecule of haemoglobin can carry upto 4 molecules of oxygen.

* Haemoglobin also transports about 23 per cent of carbon dioxide as **carbamino-haemoglobin**.

* Haemoglobin also acts as buffer and helps in maintaining a constant pH. It is so as haemoglobin is normally negatively charged (Hb^-). Addition of hydrogen ions is neutralised by Hb^- by forming **acid haemoglobin** (H.Hb) which releases hydrogen ions to neutralise basic compounds.

***(ii)* Leucocytes or White blood corpuscles (W.B.Cs.)**

Shape. These are rounded or amoeboid, nucleated, non-pigmented cells. These are wandering cells and are capable of coming out of blood capillaries by amoeboid movements, called **diapedesis.**

Size. WBCs are larger than RBCs and their size range is 8-15 μm.

Number. WBCs are much less in number than RBCs (1 : 600). Total number of leucocytes per microlitre or per cubic millimetre is called **total leucocyte count** (TLC). The number of WBCs in a healthy person ranges from 5,000 to 10,000 per cubic millimetre of whole blood. Average WBC count is **7,000 per cubic millimetre of blood**. But in an acute infection like appendicitis or pneumonia, the total leucocytes increase upto 20,000 to 30,000 per cubic millimetre of blood. This rise in

WBC count is called **leucocytosis** while the fall of WBC count below 4,000, is called **leucopenia** *e.g.*, in folic acid deficiency and tuberculosis. The formation of leucocytes occurs in bone marrow, Peyer's patches, lymph nodes, thymus, spleen etc. and is called **leucopoiesis**.

Types. On the basis of **cytoplasmic granules**, the leucocytes are divided into following **two categories**:

Granulocytes and Agranulocytes.

Granulocytes (Fig. 40). These have granular cytoplasm and lobed nucleus, so also called **polymorphonuclear leucocytes.** These are produced in the red bone-marrow from the precursor cells called **myeloblasts (myeloid tissue)**. These form about **65%** of total leucocytes (6.5×10^9 per litre). These are of **three sub-types** on the basis of the **shapes of their nuclei** and the **staining reactions of their granules :**

***Neutrophils.** These comprise about **62%** (Range is **60-65%**) of the total number of white cells so **most abundant** sub-type. These vary in size from 10 to 12 µm. The cytoplasm is with fine granules which stain with both acidic and basic dyes so appear violet in colour. The nucleus is 3-5 lobed. The life span is of 10-12 hours. These are the **chief phagocytic cells** of the body so are called **soldiers** of the body. These are attracted to an infected area by **chemotaxis**. If the infection is massive or microbes are very virulent, many neutrophils die, then it is known as **pus.** A localized accumulation of pus is called an **abscess**. Neutrophils also help in **sex-differentiation** as the neutrophils of female show a '**drum stick**' or '**barr-body**'. It represents an inactivated X-chromosome, so also called **sex chromatin.**

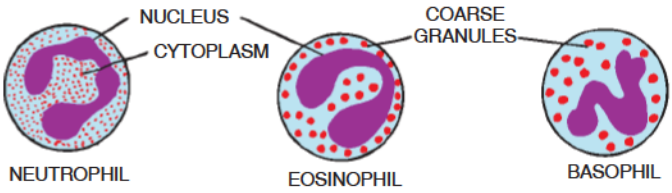


Fig. 40. Agranulocytes.

***Basophils.** These comprise about **0.5-1**% of the TLC so are **least in number.** These vary in size from 8-10 µm. The cytoplasmic granules are coarse which take up basic stains like **methylene blue,** so appear blue in colour. The nucleus is 2 or 3 lobed or S-shaped. Their life-span is 8-12 hours. Basophils **secrete heparin, serotonin and histamine** and thus have important role in local anticoagulation and formation of ground substance.

***Acidophils.** These constitute about **2-3%** of the TLC. Their size range is 10-15 µm. The cytoplasmic granules are coarse and take acidic stains like **eosin,** so also called **eosinophils**. The nucleus is bilobed. The life span is of 14 hours. These increase in number in allergic diseases, such as **asthma** or **hay fever,** and in parasitic infections *e.g.* **Ascariasis.** These also help in **healing of wounds** as destroy toxins of the microbes. These are non-phagocytic.

Agranulocytes (Fig. 41). These are non-granular white blood cells that contain non-lobulated nuclei. These form about **35%** of the total leucocytes (3.5×10^9 per litre). These are divided in **two sub-types :**

Monocytes. These are the **largest sized leucocytes** and may be upto 20 µm. These form about **5.3%** of all the leucocytes. The nucleus is oval, kidney or horse-shoe shaped and is usually excentric. These are usually formed in the lymph-nodes and the spleen from the precursor cells called **monoblasts**. These are highly motile and phagocytic in action and engulf the bacteria so these form the **second line of defence**. These also differentiate into **macrophages** or **scavenger cells** which remove the damaged and dead cells to clean the body.

Lymphocytes. These constitute about **20-30%** of TLC. Their size ranges from 8 to 12 µm. The nucleus is large and rounded so that cytoplasm forms a thin peripheral layer. These are formed in the thymus and lymphoid tissues like lymph nodes, spleen, tonsils etc. from the precursor cells called **lymphoblasts.** Primary function of the lymphocytes is to produce **antibodies and opsonins.** These are of two sub-types: **B-lymphocytes** and **T-lymphocytes**.

(iii) Blood-platelets (Fig. 42). These are **smallest sized blood corpuscles** and have a diameter of 2-3 µm.

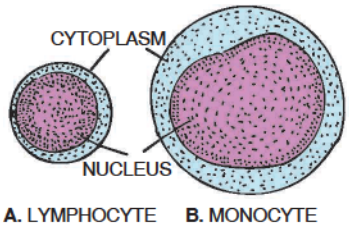


Fig. 41. Agranulocytes.

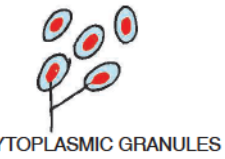


Fig. 42. Blood platelets.

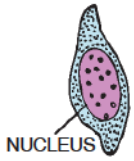


Fig. 43. Thrombocyte of frog.

These are colourless and oval-shaped cytoplasmic fragments formed from the giant cells called **megakaryocytes** of bone-marrow. These are non-nucleated. Each has a mass of basophilic granules at the centre so giving the appearance of a nucleus. Their number varies from **150,000 to 350,000 million per cubic mm** of blood. Their life span is of about one week (average 10 days) after which these are phagocytosed by leucocytes. These play major role in the process of blood clotting. At injury, the platelets release a number of **platelet factors** and an enzyme **thromboplastin** which cause the coagulation of blood to prevent excessive bleeding. Blood platelets also secrete a vasoconstrictor called **serotonin** which causes constriction of blood vessels to reduce the blood loss.

Thrombocytes (Fig. 43), also called **spindle cells,** are spindle-shaped and nucleated cells found in blood of vertebrates other than mammals. Nucleus is oval shaped. These help in blood clotting in other vertebrates.

2. LYMPH

Lymph is a **white vascular connective tissue.**

Physical properties. It is highly translucent, alkaline fluid present in the lymph vessels and between the blood capillaries and the tissues. It also forms the **tissue fluid** which surrounds the body tissues.

Composition. Lymph is formed of **two parts :**

(a) Plasma. It is fluidy matrix of lymph. It is similar to that of the blood except that it has less proteins, calcium and phosphorus but with more glucose. It is actually derived from the blood by the process of **ultrafiltration.**

(b) Leucocytes (WBCs). These are floating amoeboid cells of lymph. These also resemble with those of blood. These also come from the blood by **diapedesis**. The main cells are **lymphocytes.** These are also less in number.

So the lymph is the blood minus RBCs, platelets and some proteins.

Functions

(a) The lymph acts as **middle man** between the blood and the tissue cells and helps in **exchange of materials** between blood and cells.

(b) It also keeps the tissues moist.

(c) It also transports fat food from the intestine to the venous blood.

Table 23. Characteristics of different types of Leucocytes.

Characters	Neutrophils	Basophils	Acidophils	Monocytes	Lymphocytes
1. Percentage of leucocytes	62%	0.5-1%	2-3%	5.3%	20-30%
2. Diameter	10-12 µm	8-10 µm	10-15 µm	12-15 µm	8-12 µm
3. Nucleus	Multilobed	S-shaped	Bilobed	Kidney-shaped	Rounded
4. Cytoplasm	Neutrophilic	Basophilic	Eosinophilic	Basophilic	Basophilic
5. Granules	Fine granular	Coarse granular	Coarse granular	Absent	Absent
6. Life span	10-12 hours	8-12 hours	14 hours	10-20 hours	Months to years
7. Formation	Red bone marrow	Red bone marrow	Red bone marrow	Spleen and lymph nodes	Lymph nodes and Thymus
8. Functions	Soldiers acting as phagocytes	Heparin, serotonin and histamine secretion	Antiallergic and healing of wounds	Scavenger	Antibodies formation

Table 24. Differences between Blood and Lymph.

Characters	Blood	Lymph
1. Type of tissue	Red vascular tissue.	White vascular tissue.
2. Occurrence	In blood vessels.	In lymph vessels; around body tissues.
3. Composition	Formed of plasma, erythrocytes, leucocytes and platelets. Neutrophils are most abundant.	Formed of plasma and leucocytes only. Erythrocytes and platelets are absent. Lymphocytes are most abundant.
4. Haemoglobin	Present in RBCs.	Absent.
5. Nature of plasma	Plasma has more proteins, calcium and phosphorus.	Less proteins, calcium and phosphorus.
6. Functions	Transportation of materials inside the body.	Acts as middle-man between blood and body cells.

SUPPLEMENT YOUR KNOWLEDGE

- **Extracellular fluid (ECF) :** Sum of the fluids, present outside the cells in the animal body e.g. blood, lymph, interstitial fluid, pericardial fluid, pleural fluid, etc
- Human blood is **five times more viscous** than water.
- Blood is also called **liquid tissue.**
- Salts form 0.9% of blood plasma of man.
- **Erythrocytopaenia :** Decrease in the number of RBCs. It causes **hypoxia** in the body tissues.
- In man, the erythropoeisis is completed in about 72 hours.
- Haemoglobin amount is less in women than men because women undergo menstruation.
- RBC count is more in people living in hilly areas to compensate atmospheric hypoxia.
- In early few weeks of embryonic development, nucleated RBCs are produced in yolk sac. In later embryonic stages, erythropoeisis occurs in liver and spleen but from birth onwards. RBCs are formed in the red bone marrow of long bones.
- Low TLC indicates viral infection , malaria, typhoid or TB.
- Cytoplasmic granules of neutrophils are lysosomes and Golgi bodies of the cell.
- **Platelets** are found in the blood of only mammals.
- **Anticoagulants :** Chemicals which prevent the blood clotting e.g. **Heparin** secreted by liver cells and basophils of blood.
- **Thrombosis :** Formation of a blood dot (called **thrombus**) inside the blood vessel.
- **Fibrinolysis :** Dissolution of blood clot by an enzyme called **plasmin.**

PRACTICE PROBLEMS – VASCULAR CONNECTIVE TISSUE

52. How does vascular tissue differ from other type of connective tissue?
53. Name main types of blood proteins.
54. Which blood proteins are involved in blood clotting?
55. What is significance of biconcave shape of RBCs.
56. Give the RBC-count of normal man and woman.
57. What is polycythaemia?
58. Name the instrument used to measure RBC count.
59. Why are RBCs anaerobic in their respiration?
60. Give haemoglobin count in a normal woman and man.
61. Name the instrument used to measure Hb-count.
62. What is life span of human RBC?
63. Why is spleen called graveyard of RBCs?
64. Define haemolysis.
65. Why is spleen called blood bank of the body?
66. What is RBC : WBC ratio in a normal adult man?
67. Why are granulocytes called polymorphonuclear corpuscles?
68. Name the most abundant and least number of leucocytes of blood.
69. Why are neutrophils called soldiers of the body?
70. Give the function of monocytes.
71. Give the function of lymphocytes.
72. What are blood platelets? Give their function.
73. How do thrombocytes differ from the blood platelets?
74. What is diapedesis?
75. Why is lymph called middle man of body?
76. What is blood coagulation? Give its significance.
77. How does serum differ from blood plasma?
78. What is role of vitamin K in blood clotting?
79. Define thrombosis.
80. What is haematocrit value?

ANSWERS TO PRACTICE PROBLEMS

52. It is **fluidy** and **fibre-tree**, and its matrix is not secreted by the cells.
53. (i) Albumin (ii) Globulins (iii) Fibrinogen (iv) Prothrombin.
54. **Prothrombin** and **fibrinogen** proteins of blood plasma help in blood clotting at the injuries.
55. It increases the surface area to volume ratio so increases exchanging power of cells.
56. (i) Man = 5-5.5 10^6 per cubic mm. (ii) Woman = 4.5 - 5.0 10^6 per cubic mm.
57. Increase in RBC count is called polycythemia.
58. **Haemocytometer.**
59. Due to absence of mitochondria.
60. (i) Man = 14.5 ± 2 gram % (ii) Woman = 12.0 ± 2 2 gram %
61. **Haemometer.**
62. 115 - 120 days.
63. Spleen is main site of **haemolysis of RBCs**.
64. Destruction of old and dead RBCs by the reticuloendothelial cells of liver, spleen, bone marrow, etc. is called **haemolysis**.
65. Because the excess of RBCs is stored in the spleen.
66. RBC : WBC ratio is **600 : 1.**
67. As the nucleus of granulocytes is 2 or 3 or multilobed.
68. Most abundant leucocytes are **neutrophils** (about 62%) ,while least number of leucocytes are **basophils.**
69. As these are **chief phagocytic cells** of blood.
70. Monocytes act as **scavengers** and eat upon the damaged and dead cells of body.
71. These secrete **antibodies** which form immune system of body.
72. These are smallest sized blood corpuscles of human blood. These are cytoplasmic fragments and help in blood clotting at the injury as these release an enzyme **thromboplastin.**
73. Thrombocytes are spindle-shaped nucleated corpuscles of blood of non-mammals, while blood platelets are oval-shaped, non-nucleated cytoplasmic fragments of blood of mammals.
74. WBCs can move outside the blood capillaries by their amoeboid movements to eat the germs.
75. It forms the **tissue fluid** which helps in exchange of materials between the body cells and blood.
76. It involves the property of blood to change from sol to gel state at the site of injury. It prevents the excessive bleeding of blood.
77. Serum is blood plasma minus blood clotting proteins like prothrombin and fibrinogen.
78. Vitamin K promotes the formation of prothrombin in the liver cells.
79. Formation of a blood clot inside the blood vessel.
80. It is percentage of blood corpuscles. It is also called **packed cell volume.**

ADDITIONAL USEFUL INFORMATIONS ABOUT VASCULAR CONNECTIVE TISSUE FOR COMPETITIVE EXAMINATIONS

- *Total amount of ECF in a normal adult human is about **15 litres.** Water forms about 45 per cent of ECF.*
- ***Haemotology :** Study of blood with the help of **Leishmann stain.***
- *Blood is commonly called **river of life.***
- *There is about **6.8 litres of blood** and **2 litres of lymph** in a normal human adult.*
- *Average normal blood sugar level is **80-100 mg per 100 ml** of blood but is **90-120 mg/decilitre of blood** about 12 hours after a meal; normal urea level is **17-30 mg per 100 ml** of blood, while normal cholesterol level is **80-180 mg per 100 ml** of blood.*
- ***Haematocrit value :** Also called **Packed Cell Volume** and is percentage of blood cells. It is about **40 - 45%** in man and **36%** in woman, but it may fall as low as 10% and may rise as high as 80% in diseased condition.*
- ***Wintrobe tube :** Instrument used to determine haematocrit value.*
- ***Westergren's pipette :** Used to measure ESR.*
- ***Rouleaux :** Tendency of RBCs to stick with one another to form rows.*
- ***RBC size :** Largest sized RBCs (75 μm) found in Amphiuma (Salamander) while smallest sized RBCs (2.5 μm) are found in Tragulus (musk deer). Among mammals, largest sized RBCs are found in elephant.*
- ***Normovolemia :** Normal blood volume.*
- ***Hypovolemia :** Decreased blood volume.*

- *Hypervolemia : Increased blood volume.*
- *Haemoglobin amount is highest in faetus while it is 23 gm per cent of blood at birth.*
- *People living at high altitudes have high RBC count to compensate atmospheric hypoxia.*
- *Life span of RBCs is of 50-70 days in rabbit and of 100 days in frog.*
- *Stem cells of bone marrow responsible for RBCs formation are called **haemocytoblasts or myeloblasts.***
- *Every gram of Hb transports about 1.33 ml of oxygen so about 19.80 ml of oxygen is transported by 100 ml of blood.*
- *Relative percentage of leucocytes is called **differential leucocyte count (DLC).***
- *B-Lymphocytes form **humoral immune system**, while T-lymphocytes form **cell mediated immune system.***
- *Decrease in number of thrombocytes is called **thrombocytopenia;** (**e.g., in purpurea disease**)while increase in number of thrombocytes is called **thrombocytosis.***
- *Lymph is commonly called **filtered blood.***
- ***ESR (Erythrocyte sedimentation rate) :** Rate of settling of RBCs and is calculated with **Westergren's pipette.***
- *Serum differs from blood plasma in being without blood clotting proteins like prothrombin and fibrinogen, so cannot clot the blood.*
- ***Thrombosis :** Occurs in the veins as blood flows slowly in the veins than the arteries.*
- *Iron is stored in bone marrow in the form of **ferritin.***
- ***Haemocyanin :** Copper – containing blue coloured pigment found in the blood plasma of certain crustaceans like prawns and crabs and most of mollusks.*

IV. NERVOUS TISSUE

Origin. Nervous tissue is **ectodermal** in origin. It exerts the greatest control over the body's responsiveness to changing conditions.

Properties

1. Excitability. Nerve cells **(neurons)** are **excitable** by external and internal stimuli (changes initiating the responses in the body parts). A **stimulus** of adequate strength causes the depolarization of the neuron locally and initiates a **nerve impulse.**

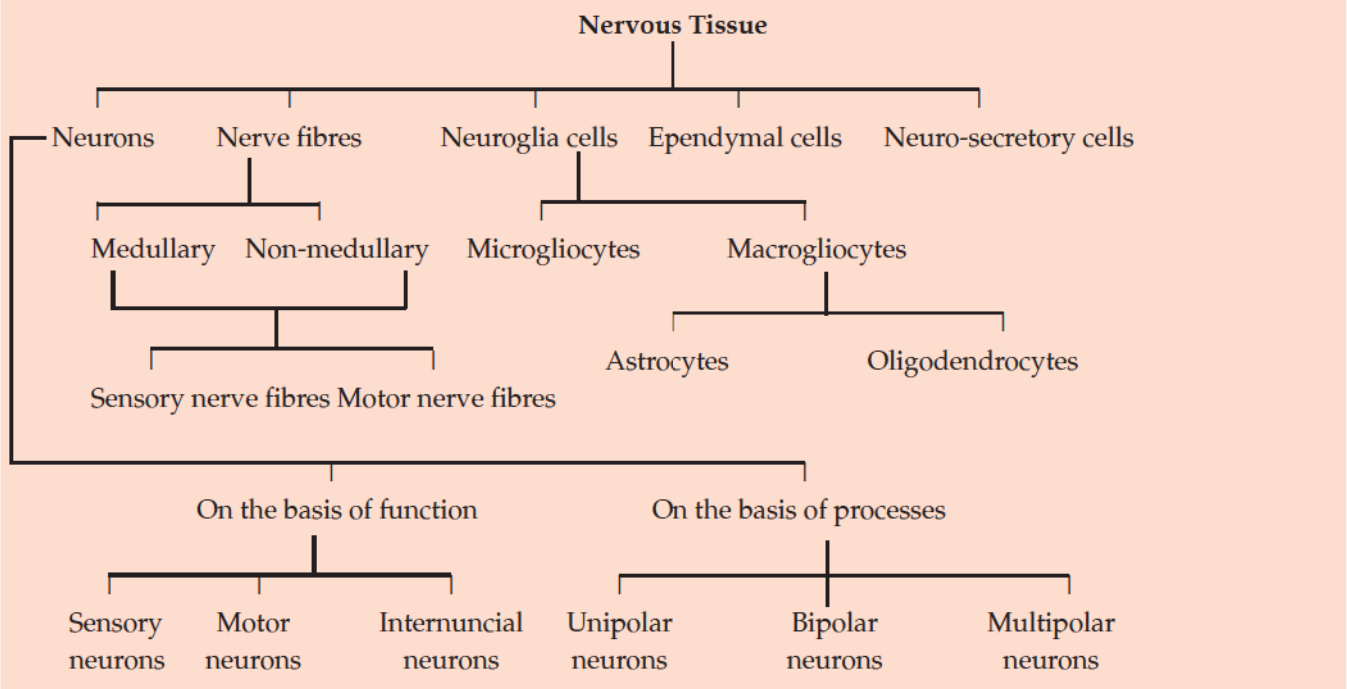
2. Conductivity. The neurons are capable of conducting this depolarization as a wave along their length in a particular direction either to other nerve cells or to effectors like muscles and glands which give the **response**.

Therefore, **excitability** and **conductivity** are the two fundamental properties of nervous tissues.

3. There is **no intercellular matrix** between neurons.

4. These have permanently **lost the power of division** as have **no centriole.**

Table 25. Components of Nervous Tissue.



Composition. Nervous tissue is formed of four types of cells so it is **compound tissue:**

(a) Neurons (nerve cells).

(b) Neuroglia.

(c) Ependymal cells.

(d) Neuro-secretory cells.

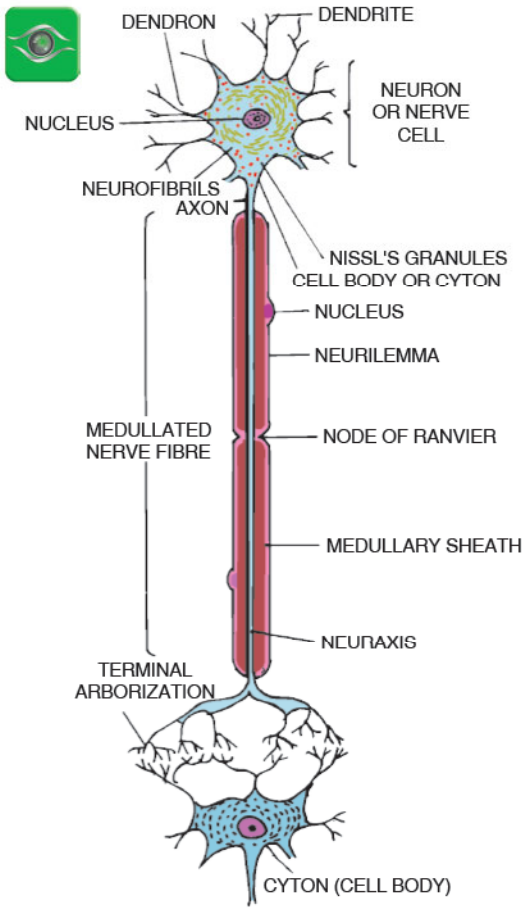


Fig. 44. Neuron and nerve fibres.

(a) Neurons (Fig. 44). A neuron is a nerve cell with all its branches. It is the **structural and functional unit of nervous system.** Neuron is the **communication unit** of most nervous systems. It may be elongated over 100 cm. Neurons can detect, receive and conduct the nerve impulses to various parts of the body.

Structure. A neuron is formed of **two parts :**

(i) **Cyton.** It is also called **perikaryon** or **soma** or **cell body.** It is of variable shape. Its granular cytoplasm is called **neuroplasm** which has following structures :

*A large, spherical, centrally placed **nucleus** with a single **nucleolus.**

*Numerous fine threads, called **neurofibrils,** for the conduction of nerve impulses.

*A number of small, basophilic granules of varying shapes called **Nissl's granules.**

*Neuroplasm has large number of mitochondria to provide high energy for impulse conduction.

(ii) **Nerve processes.** These are one or more protoplasmic processes arising from the cyton. These are of **two types :**

***Dendrites or Dendrons.** These are one or more small sized tapering processes. Each is highly branched to form the **terminal arborization**. These are **afferent** in nature and conduct the nerve impulses towards the cyton so also called **receptive input region**. These have both Nissl's granules and neurofibrils.

***Axon.** It is single, long and cylindrical process whose primary function is to conduct the nerve impulses away from the cyton. It is, therefore, **efferent or conducting region** in nature. It is the **longest nerve process** of a neuron. The plasma membrane of axon is called **axolemma** while the cytoplasm is called **axoplasm**. It has only neurofibrils while the Nissl's granules are absent in it. It may form a number of branches called **terminal arborization**, each branch of which forms a junction with muscle fibre (called **neuro-muscular junction**) or with dendron or cyton of another neuron (called **synapse**) or gland cell.

Arrangement of Neurons. The neurons may lie end to end forming a chain or may be aggregated into a cell mass. A cell mass of sensory neurons in the brain or spinal cord is called **nucleus** while a cell mass of sensory neurons outside the CNS in cranial and spinal nerve is called **ganglion** (a mass of about 50,000 neurons). Each neuron receives a nerve impulse through its dendrons and passes it to the next neuron through its axon. An axon ends into a number of branches, the **terminal arborization,** the ends of which form knob-like swellings called **synaptic knobs** (or **axon terminal**) which come to lie very close to the dendrons of next neuron. There is a microscopic gap of about 200Å called **synaptic cleft.** Such a junction between synaptic knob of axon of one neuron and dendron of next neuron is called **synapse**. Nerve impulses are transmitted from axon to dendron with the help of chemicals called **neurotransmitters,** produced by the secretory vesicles of the synaptic knobs. These neurotransmitters cause stimulation or inhibition of next neurons or effector cell.

Table 26. Differences between Axon and Dendron.

Characters	Axon	Dendron
1. Number	Always single.	May be one or more in number.
2. Structure	Formed of neuroplasm with only neurofibrils but no Nissl's bodies.	Formed of neuroplasm with both neurofibrils and Nissl's bodies.
3. Size	Long sized processes.	Small sized processes.
4. Direction of nerve impulses	Always away from the cell body.	Always towards the cell body.

These may be **acetylcholine** or **adrenalin (epinephrine).**

Types of Neurons:

1. On the basis of functions. Neurons are divided into **three categories :**

(i) Sensory (Afferent) neuron. These are found in **sense organs.** Their dendrons receive the nerve impulse from receptor cell while their axon forms the synapse with dendron of the next neuron *e.g.* **olfactoreceptors** and **gustatoreceptors.**

(ii) Internuncial neurons. These are located **in the dorsal horn of the spinal cord.** Their dendrons form the synapse with the axon of sensory neuron while their axon forms the synapse with the dendron of the motor neuron.

(iii) Motor (Efferent) neurons. These are always present **in the ventral horn of the spinal cord.** Their axon ends into the muscle fibres or gland cells (effector organs) which respond to the stimuli.

2. On the basis of number of nerve processes. Neurons are of **three types (Fig. 45) :**

(i) Unipolar neurons. In these neurons, only one nerve process arises from the cyton which acts as axon but there is no dendron. These are found **only in early embryos** but are absent in adult human beings. The unipolar neuron of the adult gives rise to a single nerve process, which immediately divides into a dendron and an axon. Such unipolar neurons are called **pseudo–unipolar neurons (Fig. 45 A).** These are found in the **dorsal root ganglia** of spinal nerves and in the roots of V, IX and X cranial nerves.

(ii) Bipolar neurons (Fig 45 B). In these neurons, the cyton gives rise to two nerve processes out of which one acts as an axon while other acts as a dendron. These are found in the **olfactory epithelium** of nasal chamber and **retina** of eye.

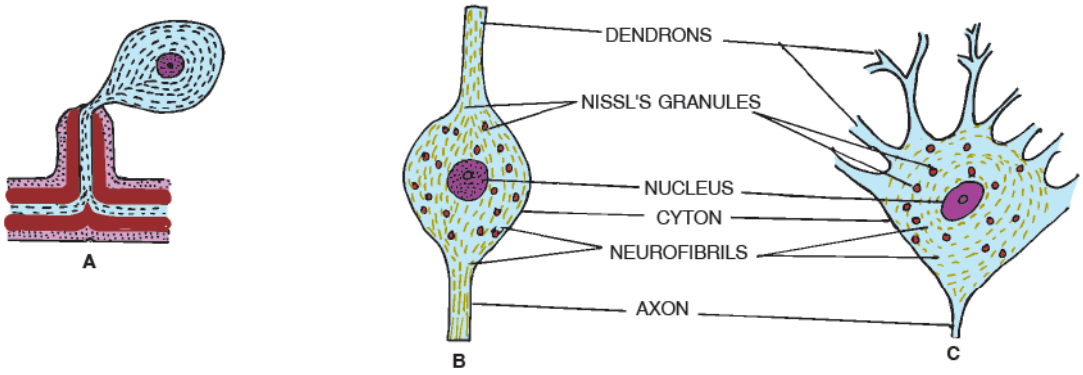


Fig. 45. Types of neurons. **A.** Pseudounipolar, **B.** Bipolar, **C.** Multipolar.

(iii) Multipolar neurons (Fig. 45 C). In these neurons, the cyton gives rise to 3 or more nerve processes out of which one acts as an axon while remaining nerve processes act as dendrons. These are found in the **cerebral cortex of Brain** and the **ganglia of autonomic nervous system.** Motor neurons and internuncial neurons of CNS are multipolar neurons.

Types of Nerve fibres (Figs. 46 and 47)

Definition. An axon of a neuron covered with one or two sheaths is called a **nerve fibre.** Nerve fibres are involved in the **conduction of nerve impulses.**

On the basis of number of sheaths. Nerve fibres are of **two types :**

1. Medullated or myelinated nerve fibres (Fig. 46) :

(i) Occurrence. These are found in the **white matter** of brain and spinal cord; and **cranial** and **spinal nerves.**

(ii) Structure. A medullated nerve fibre is formed of a central axial cylinder called **neuraxis** which is covered by two sheaths.

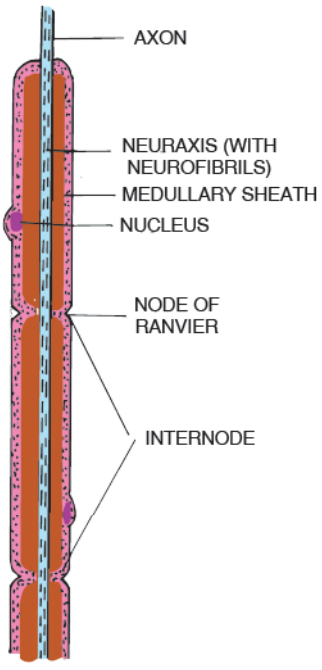


Fig. 46. Medullated nerve fibre.

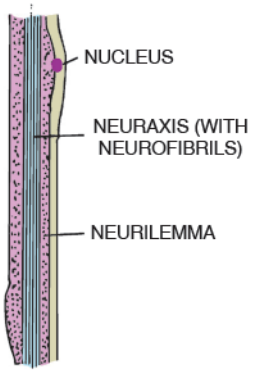


Fig. 47. Non-medullated nerve fibre.

Table 27. Distinguish between Medullated and Non-medullated nerve fibres.

Characters	Medullated nerve fibres	Non-medullated nerve fibres
1. Occurrence	Found in **white matter** of brain, spinal cord, cranial and spinal nerves.	Found in **grey matter** of brain and spinal cord, and in autonomic nervous systems.
2. Sheaths	Neuraxis covered by inner medullary sheath and outer neurilemma.	Neuraxis covered by only neurilemma. **Medullary sheath is absent.**
3. Nodes of Ranvier and internodes	Present.	Absent.
4. Diameter	More.	Less.
5. Colour	White.	Grey.
6. Speed of conduction of nerve impulses	Faster due to saltatory conduction of nerve impulses.	Slower.
7. Collateral branches	Present.	Absent.

* **Medullary or Myelin sheath.** It is inner, thicker sheath which is formed of shining white fatty substance called **myelin.** The medullary sheath forms a continuous layer in brain and spinal cord but is discontinuous at regular intervals in peripheral nervous system. The points of absence of medullary sheath are called **nodes of Ranvier** (with only Na^+–channels), while the part of the medullated nerve fibre between two adjacent nodes is called an **internode.** The **collateral branches** always arise at the nodes and are perpendicular to the neuraxis. Medullary sheath forms insulating coat and prevents the loss of energy during conduction of nerve impulses.

* **Neurilemma**. It is transparent, outer and thinner sheath formed of tubular **sheath cells**, also called **Schwann cells,** which are placed end to end. It is the only layer over the nodes.

2. Non-medullated or Non-myelinated nerve fibres (Fig. 47) :

(i) Position. These are found in **grey matter** of brain and spinal cord. These also form the **autonomic and somatic nervous system.**

(ii) Structure. In a non-medullated nerve fibre, the central axial cylinder called **neuraxis** is covered by only neurilemma formed of **sheath** or **Schwann cells** and there is no medullary sheath so these have no nodes of Ranvier and internodes. The nuclei of sheath cells cause swellings. Neurilemma is further covered by a thin layer of areolar connective tissue. These appear grey in colour.

Schwann or Sheath cells

These are tubular cells placed end of end. **Each Schwann cell forms medullary sheath of an internode around the neuraxis of PNS**. For this, the plasma membrane of a Schwann cell extends as a double layer which gets wrapped around the axon many times. The membranes fuse and form the myelin sheath **(Fig. 48).** So the medullary sheath is formed of alternating concentric layers of lipid and protein materials. The outermost layer is formed of cytoplasm and nucleus and forms the neurilemma.

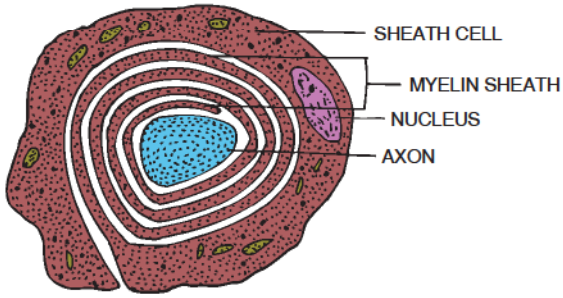


Fig. 48. A Schwann cell forming myelin sheath.

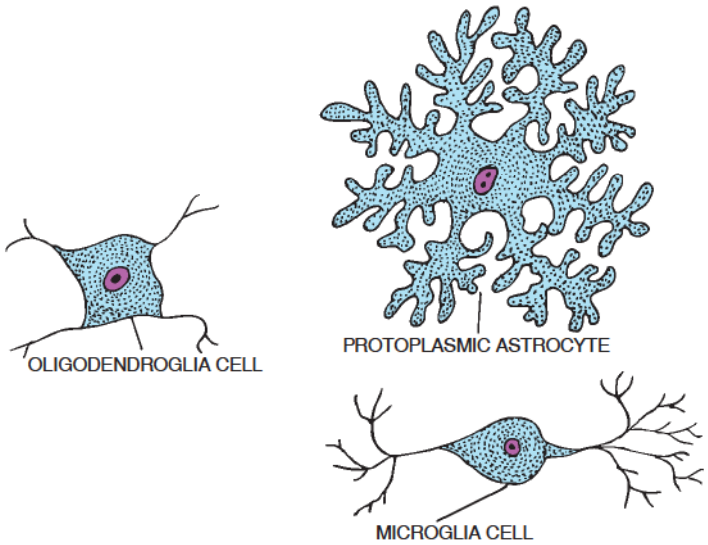


Fig. 49. Various types of neuroglia.

(b) Neuroglia or Glia cells (Fig. 49)

Position. These are non-nervous cells which lie between the neurons of the CNS, ganglia and between photoreceptors of retina of eye. These protect and support the neurons and form more than one half the volume of nervous tissue.

Types. The neuroglia cells are of **three types** :

(i) **Microglial cells (Microgliocytes).** These are smallest sized cells and spindle-shaped and form reticulo-endothelial system. These act as **phagocytic macrophages** or **scavenger cells.** These make up the primary immune system for the CNS.

(ii) **Astrocytes.** These are largest sized cells and star-shaped with several, highly branched processes present around the blood vessels. These provide **nutritive support to neurons.**

(iii) **Oligodendrocytes.** These have a few branched processes and form **insulating myelin sheath** covering of nerve fibres of CNS.

Functions : (i) These act as **packing cells** between the neurons.

(ii) These are **capable of division** and help in wear and tear of the central nervous system.

(iii) These **insulate** the adjoining neurons and prevent the lateral transmission of impulses.

(iv) These provide **nutrition** to the neurons.

(v) These act as **phagocytes** and eat up the microbes.

(vi) These help in **memory** processes.

(c) Ependymal cells. These are cuboidal and ciliated epithelial cells which line the cavities of brain **(ventricles)** and spinal cord **(central canal)**. These form an epithelium called **ependyma.** Their cilia move the cerebrospinal fluid.

(d) Neurosecretory cells (Fig. 50). These are special type of neurons of the **hypothalamus** of brain. These are endocrine in function and secrete **neurohormones** which are carried by the blood of hypophyseal portal system to anterior lobe of pituitary gland and stimulate the secretion of their trophic hormones *e.g.* TSH, STH, FSH, LH, ACTH, etc.

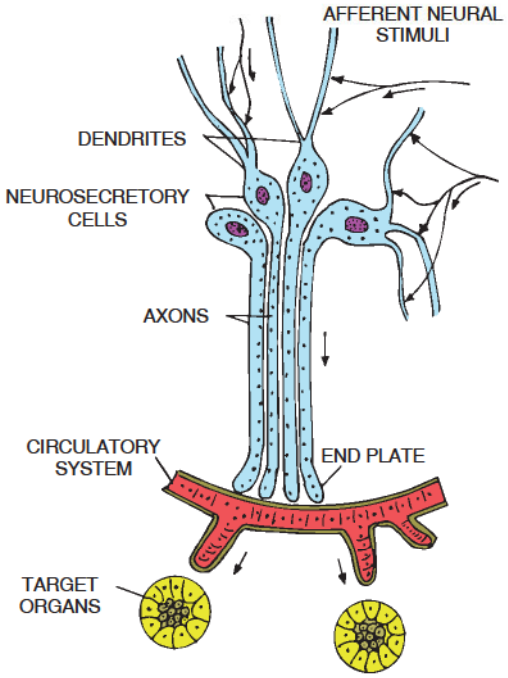


Fig. 50. Neurosecretory cells.

Table 28. Distinguish between Neuron and Neuroglia.

Characters	Neuron	Neuroglia
1. Processes	These have two types of processes– axon and dendron.	These have one type of several processes.
2. Synapse	These form synapse.	These do not form synapse.
3. Division power	These cannot divide.	These are capable of division.
4. Function	These conduct the nerve impulses.	These act as packing cells and are nutritive and defensive in function.

NOTE

- Nissl's granules are RER and sites of protein synthesis.
- **Axon hillock :** Cone-shaped part of cyton of neuron from where the axon arises and is most sensitive part of neuron.
- **Unpolarised or non–polar neurons :** Cell body gives rise to many nerve processes but there is no difference between the neurites so the impulses can travel in any direction. These are found in coelenterates and form the diffused nervous system.
- **Unipolar brush cells (UBCs)** are a class of excitatory glutamatergic internuncial neurons found in the granular cells of the cerebellar cortex. Each is formed of a rounded cyton and single dendron which divides to form a dendritic brush. It secretes glutamic acid neurotransmitter.
- **Microgliocytes** arise from mesoderm of the embryo.
- **Epineurium :** Thick white fibrous sheath on a nerve.
- **Perineurium :** A sheath around a bundle of nerve fibres.

- **Endoneurium :** A thin C.T. sheath around a nerve fibre.
- **Acetylcholine** was first neurotransmitter to be discovered.
- Synapses may be **axodentritic** (between axon and dendron of adjoining neurons) or **axosomatic** (between axon and cyton of adjoining cells.
- **Astrocytes** may be **fibrous astrocytes** (with thinner processes and are found in white matter) or **protoplasmic astrocytes** (with thicker processes and are found in grey matter of CNS).

PRACTICE PROBLEMS – NERVOUS TISSUE

81. List two fundamental properties of nerve cells.
82. Why do neurons not have division power?
83. What are Nissl's granules? Give their functions.
84. What are neurofibrils? Give their functions.
85. Name two types of nerve processes of a neuron.
86. Why is axon called efferent nerve process?
87. How do nucleus and ganglion differ from each other?
88. Define synapse.
89. What are bipolar neurons? Where are these located?
90. Where are pseudo-unipolar neurons present?
91. Name two types of nerve fibres.
92. What is medullary sheath? Give its significance.
93. What are nodes of Ranvier and internodes?
94. What are neuroglial cells? Give their functions.
95. Which cells secrete the neurilemma?

ANSWERS TO PRACTICE PROBLEMS

81. (i) Excitability and
(ii) conductivity.
82. As these have **no centriole** on differentiation.
83. These are basophillic **granules of RER** present in the neuroplasm of cyton and are the sites of protein synthesis.
84. These are **electron microscopic threads** present in the neurons which help in conduction of nerve impulses.
85. **Dendrons** and **axon.**
86. As axon conducts the **nerve impulses away** from the cyton.
87. A **nucleus** is a group of neurons inside the brain and spinal cord, while a **ganglion** is a group of neurons on the cranial and spinal nerves.
88. Synapse is a juxta position of synaptic knob of axon of a neuron with dendron of next neuron.
89. When a neuron has two nerve processes - one dendron and one axon. These are present in **retina** of eye and **olfactory epithelium** of nasal chamber.
90. These are present in the **dorsal root ganglia** of spinal nerves.
91. Medullated nerve fibres and non-medullated nerve fibres.
92. It is a whitish sheath of myelin fat present on the neuraxis (axon) of medullated nerve fibres. It **insulates the nerve fibre** and prevents the loss of energy.
93. **Nodes of Ranvier** are those points of medullated nerve fibres where medullary sheath is absent. **Internodes** are areas between the nodes of Ranvier.
94. These are non-nervous cells present between the neurons in the CNS, ganglia and retina of eye. These act as **packing cells**, provide **nutrition**, act as **phagocytes** and insulate the neurons.
95. Schwann cells.

ADDITIONAL USEFUL INFORMATIONS ABOUT NERVOUS TISSUE FOR COMPETITIVE EXAMINATIONS

- *Neurons can not be cultured in vitro as these have lost centrioles.*
- *Neuron is the **longest cell** of body.*
- ***Neuroblasts** : Neurons forming cells.*
- ***Neurology** : Study of nervous system and its disorders.*
- *Nissl's granules are also called **Trigoid granules** and are formed of RER, so are basophillic (with RNA).*
- *Dendrons are **afferent** in nature, while axon is **efferent** in nature.*
- *Dendrons are always **non-myelinated**, while axon may be **myelinated or non-myelinated.***
- *Giant squid (Loligo) has axons of about 1500 µm in diameter.*
- *Internuncial neurons are called **association neurons** when their axon synapses with the dendron of motor neuron of same side, while these are called **commissural neurons** when their axon synapses with dendron of motor neuron of opposite side.*
- *Speed of conduction of nerve impulses is faster (about 20 times) on medullated nerve fibres due to **saltatory conduction.***
- *Neuroglial cells are about **ten times more numerous** than the neurons.*
- *Nervous tissue has six types of neuroglia out of which satellite cells (surround the neuronal cell bodies) and Schwann cells, are two kinds of neuroglia of PNS, while astrocytes, microglial cells, oligodendrocytes and ependymal cells are **neuroglia of CNS.***
- *Myelin sheath is the plasma membrane of overlying Schwann cell or of oligodendrocyte wrapped around the axon several times in a spiral manner.*

Table 29. Distinguish between the Four Types of Tissues.

Characters	Epithelial tissue	Connective tissue	Muscular tissue	Nervous tissue
1. Types of cells	Formed of same type of cells in a particular sub-type *e.g.* squamous, cuboidal or columnar.	Different type of cells in a sub-type *e.g.* histiocytes, mast cells, adipocytes etc.	Same type of cells *e.g.* muscle fibres.	Different type of cells *e.g.* neurons, neuroglia, etc.
2. Intercellular spaces	No intercellular spaces between the cells.	Large intercellular spaces between the cells.	No intercellular spaces	Cells are moderately compact.
3. Basement membrane	Present	Absent	Absent	Absent
4. Sub-types	(i) Simple (ii) Pseudostratified (iii) Stratified	(i) Areolar connective tissue. (ii) Connective tissues like adipose, bone, cartilage, blood etc.	(i) Skeletal muscles. (ii) Smooth muscles. (iii) Cardiac muscles.	(i) Myelinated nerve fibres. (ii) Non-myelinated nerve fibres.
5. Function	Covering, protection, secretion, sensory etc.	Intercommunication of various tissues.	Movement and locomotion.	These conduct nerve impulses.

ORGAN AND ORGAN-SYSTEM ORGANISATION

This has already been discussed in chapter - 4

MORPHOLOGY OF ANIMALS

I. PHERETIMA POSTHUMA (EARTHWORM)

Phylum ..... **Annelida** (Ring-like grooves called annuli; metameric segmentation and nephridia).

Class..... **Oligochaeta** (Permanent clitellum; a few setae per segment).

Habitat

Earthworms are **terrestrial and fossorial** annelid found in soft and moist soil of gardens, lawns, fields etc. rich in dead plant material. There are about 590 species of earthworms in India. Common species are *Pheretima posthuma* (India) and *Lumbricus* (European spp.).

Habits

(i) Activity. Earthworm is **nocturnal**.

(ii) Mode of living. It is **fossorial** and lives in a self-dug burrow made by pushing or eating soil.

(iii) Locomotion (Fig. 51). It shows **creeping type** locomotion with the help of contraction and relaxation of body muscles and is aided by setae and coelomic fluid (acts as **hydraulic skeleton** against which muscles act). The simultaneous contraction of circular muscles and relaxation of longitudinal muscles of a few segments make that part to lengthen. The setae are protruded and embedded in the soil to anchor that part. Now the circular muscles relax and longitudinal muscles contract which make that part to shorten which pulls the posterior part. This wave of contraction and relaxation extends anteroposteriorly. Earthworms move at the rate of 15 cm per minute.

(iv) Respiration. It shows **cutaneous respiration** through thin, moist and highly vascular body wall.

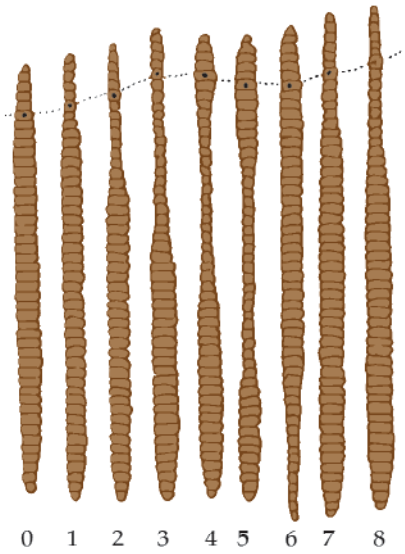


Fig. 51. *Pheretima* : Locomotion.

(v) Feeding. It is **detritivorous** but mainly feeds upon humus present in the soil.

(vi) Reproduction. Earthworm is **hermaphrodite** or **bisexual** but shows reciprocal cross-fertilization due to **protandrous** condition. They breed in the rainy season. Development is direct and occurs in ootheca.

(vii) Regeneration. Earthworms have high power of regeneration.

EXTERNAL MORPHOLOGY – FIG. 52

(A) Shape, size, colour and symmetry. Earthworm has an elongated and narrow cylindrical body having anterior pointed and posterior blunt end. It lacks distinct head. It is reddish about 150 mm in length and 3-5 mm in diameter. It is reddish brown-coloured and more darker on dorsal side than ventral side due to presence of porphyrin pigment. Dorsal side also has a **dorsal line** due to dorsal blood vessel. It is **bilateral symmetrical.**

(B) Segmentation. Earthworm is formed of 100-120 segments, called **metameres** or **somites,** due to presence of ring-like grooves called **annuli.** In earthworm like other annelids, external division of body corresponds with internal segmentation of body cavity, so is called **metameric segmentation.** The first segment is called **peristomium** or **buccal segment** which is produced into a fleshy lobe-like structure called **prostomium** which hangs over the mouth.

(C) Clitellum (or Cingulum) (Fig. 53A). It is glandular collar-like thickening which surrounds 14th, 15th and 16th segments. It forms **ootheca** or **cocoon** during breeding season. It divides the body into three parts ; **preclitellar** (first 13 segments) **clitellar** (of 3 segments *i.e.* 14th, 15th and 16th segments) and **post-clitellar part** (form 17th to last segments). Clitellum is absent in the immature worm. It indicates maturity of worm.

(D) Setae or chaetae(Fig. 52). These are S-shaped microscopic chitinous structures present in rings in all the segments **(perichaetine arrangement)** except the first,

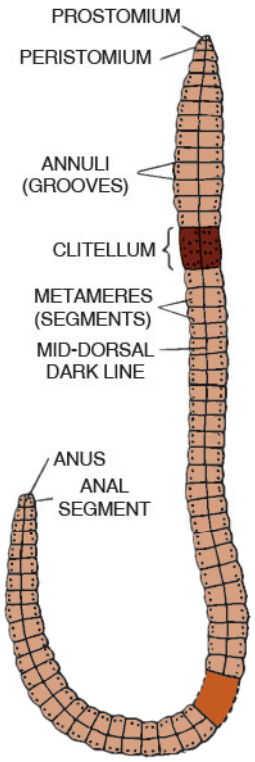


Fig. 52. *Pheretima posthuma* in dorsal view.

clitellar and anal segments . These are 80-120 in number per segment. Setae help in locomotion and copulation.

(E) Apertures (Fig. 53) : (i) Mouth is a large sized, transverse, crescentic aperture present at anterior end of first segment (called **peristomium** or **buccal segment)** and is overhung by a fleshy lobe called **prostomium** which acts as a wedge to force open cracks in the soil and is also sensory in function.

(ii) Anus is a slit–like vertical aperture present at end of last segment called **pygidium** or **anal segment.** It is for **egestion.** So earthworm has no tail.

(iii) Female gonopore is minute circular aperture located on mid–ventral side of 14th segment of clitellar region of body. Ova are passed into ootheca through it.

(iv) Male gonopores are one pair of crescentic apertures present on ventro–lateral sides of 18th segment. Sperms are transferred into spermathecae of another earthworm through them.

(v) Genital or copulatory papillae are two pairs of conical ridges, one pair on ventrolateral sides of each of 17th and 19th segment. These have the openings of accessory glands whose secretion helps in **copulation.**

(vi) Nephridiopores are outlets of integumentary nephridia. These are 200-250 in number in each segment except first two segments but their number is very large in the clitellar segments. These help in **excretion.**

(vii) Dorsal pores. These are minute, circular apertures present in the inter–segmental grooves on mid-dorsal side from 12th segment onward. Ist dorsal pore lies in the inter-segmental groove between 12th and 13th segments. It is absent in last segment. These

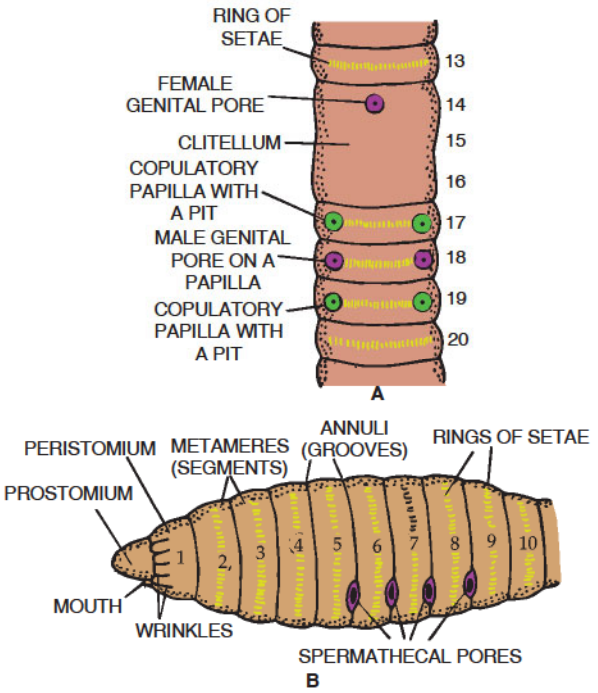


Fig. 53. *Pheretima posthuma.* **A.** Ventral view. **B.** Lateral view.

are outlets of coelomic fluid which keeps the skin moist for **respiration** and also helps in **excretion.**

(viii) Spermathecal pores (Fig. 53B). These are four pairs of slit–like apertures present on ventrolateral sides in the intersegmental grooves on ventrolateral sides of body, one pair in each of between 5th and 6th , 6th and 7th, 7th and 8th, and 8th and 9th segment. These lead into **spermathecae** which **store the sperms** received from another earthworm during copulation.

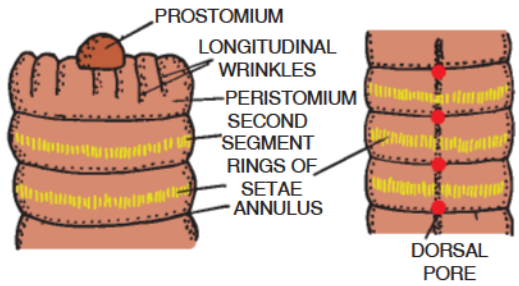


Fig. 54. *Pheretima* : **A.** Anterior end. **B.** 17 to 21 segments. Both in dorsal view.

Internal Morphology (Anatomy)

1. Body wall (Fig. 55)

Body wall of earthworm is thin, slimy and respiratory. It is formed of :

(i) Cuticle is outermost, thin, elastic, porous, **non-cellular** and **collagenous.** It is secreted by supporting cells of epidermis. It is **protective** in function.

(ii) Epidermis is single-layered columnar epithelium and is formed of mainly columnar **supporting cells,** mucus-secreting club-shaped **goblet cells,** cylindrical **albumen gland cells,** small-sized and conical **basal or replacing cells** and columnar-shaped **sensory cells.** It invaginates to form **setal sacs.**

(iii) Musculature is formed of outer thin layer of **circular muscles** and inner thicker layer of **longitudinal muscles** (present in bundles separated by connective tissue septa). Both muscle types are **smooth.**

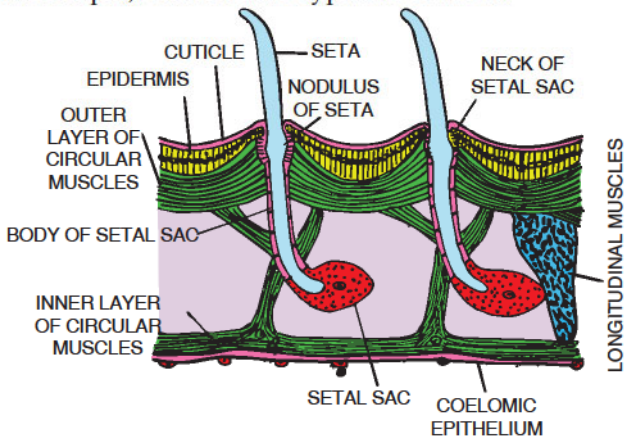


Fig. 55. *Pheretima* : T.S. body wall.

(iv) Coelomic epithelium is innermost **parietal peritoneum** and lines the coelom.

Functions. Body wall is protective, locomotory, nutritive (secretes albumen) and respiratory in function. It also gives a definite shape.

2. Coelom

Earthworms are **eucoelomate** (with true coelom) and **schizocoelomate** (coelom formed by splitting of mesoderm). It is externally lined by **parietal peritoneum** of body wall and internally lined by **visceral peritoneum** of gut wall. Coelom is divided into a series of chambers by intersegmental partitions called **septa** except the first four segments which lack septa. Ist septum lies between 4th and 5th segments. Septum is also absent between 9th and 10th segments. Coelomic chambers are filled with a milky and alkaline **coelomic fluid** which acts as **hydraulic skeleton** and helps in locomotion, respiration, distribution of materials, excretion, etc. Coelomic fluid has **coelomic corpuscles** like phagocytes, mucocytes, circular cells, eleocytes and chloragogen or yellow cells.

3. Alimentary canal (Fig. 56)

It is straight, tubular and **complete** in earthworm. It is formed of following parts :

(a) Mouth is a crescentic aperture ventral to peristomium and dorsally covered by prostomium.

(b) Buccal cavity is small and tubular. It extends from 1st to 3rd segment. It is protrusible.

(c) Pharynx is a pear-shaped sac which extends upto 4th segment. On its roof, there is a muscular and glandular **pharyngeal bulb** which has a number of unicellular **salivary glands.** It is attached to body wall

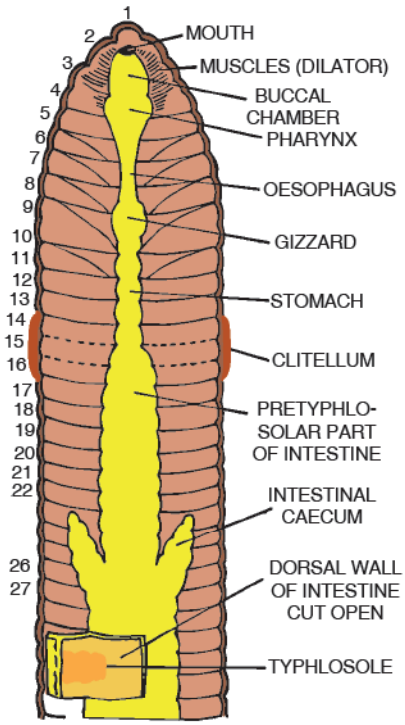


Fig. 56. Alimentary canal of earthworm.

by radial **dilator muscles** (to dilate pharynx during ingestion). It acts as a **suctorial pump** during feeding.

(d) Oesophagus or gullet is thin-walled and tubular. It extends from 5th to 7th segment.

(e) Gizzard is a thick-walled, muscular and oval sac present in 8th or 8th and 9th segments. It is **masticatory** in function.

(f) Stomach is thin-walled and tubular. It extends from 9th or 10th to 14th segment. Its epithelium is glandular and secretes a proteolytic enzyme and a secretion (by **calciferous gland**) which produces calcium and neutralizes the humic acid of soil.

(g) Intestine (Fig. 57) is **longest part** and is wide, thin-walled and tubular. It extends from 15th to last segment. It is differentiated into three parts : **Pre-typhlosolar part** (from 15th to 26th segment. In 26th segment, it gives rise one pair of conical processes called **intestinal caecae**); **Typhlosolar part** (from 27th to 95th segment. It has a well-developed fold, called **typhlosole**, hanging from its dorsal side. Typhlosole increases the surface area of digestion and absorption) and **Post-typhlosolar part** (from 96th to last segment. It is also called **rectum** as stores the faecal matter).

(h) Anus is slit-like aperture lying at the tip of last segment called **anal segment.**

Feeding. Earthworm is **omnivorous** but mainly feeds upon **humus** of decaying leaves along with soil. Ingestion is by sucking action of pharynx. The earthworm can consume upto one-third of its body weight in just one day. Food is digested by saliva (with proteolytic enzyme) of salivary gland cells and enzymes of intestinal caecae (secrete amylolytic enzyme), and epithelium of stomach and intestine. Digestion is **extracellular.** Digested food is absorbed in intestine, while undigested food and the soil are egested through anus as **worm castings** (heaps of small and rounded **pellets** commonly seen in gardens, lawns etc.) Extra calcium is expelled as **calcite.**

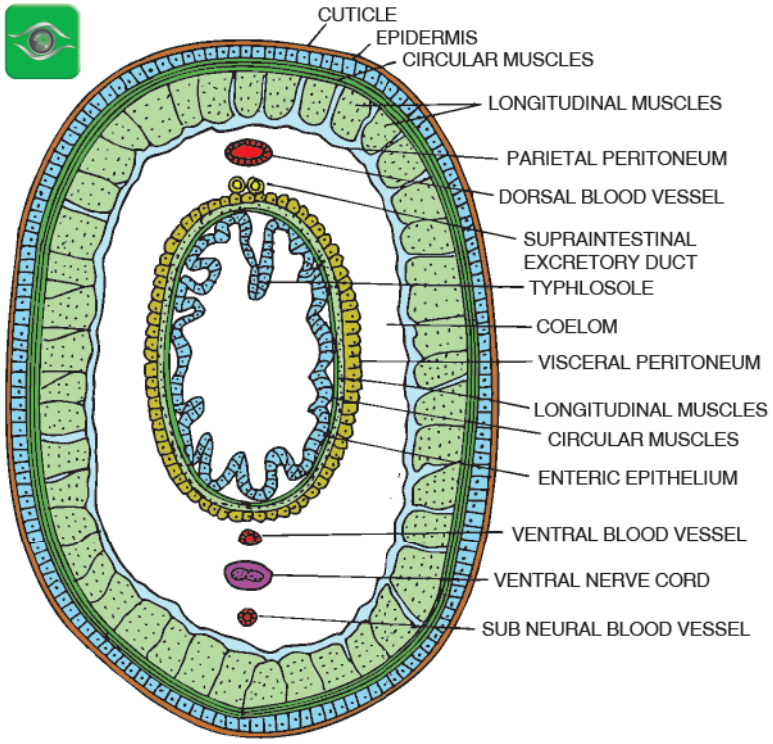


Fig. 57. T.S. Earthworm through typhlosolar region of intestine.

4. Excretory system

Excretory organs of earthworm are segmentally-arranged microscopic and coiled structures, called **nephridia** (called **micronephric nephridia** as are microscopic). These occur in all the segments of earthworm except first two segments. Depending upon the basis of their location, nephridia are of **3 types (Fig. 58) :**

(i) Septal nephridia attached on septa from 15th segment onward. Each segment of earthworm has 80 – 100 septal nephridia. Their ducts open in intestine, so also called **enteronephric nephridia.**

(ii) Integumentary nephridia attached on inner side of skin in all the segments except first two segments (i.e., from 3rd to last segment). Each segment has about 200–250 integumentary nephridia except the clitellar segments, each of which has about 2000–2500, nephridia so called **"forests of nephridia."** Their ducts open on body surface, so called **ectonephric nephridia.**

(iii) Pharyngeal nephridia present in 3 pairs of groups, one pair in each of 4th, 5th and 6th segments. Their ducts open in buccal cavity or pharynx. So also called **enteronephric nephridia.**

Chloragogen or **yellow cells** of coelomic fluid take up the excretory matter from the blood and store them as yellow granules called **chloragosomes.** When full of wastes, these are expelled out through dorsal pores so are excretory in function. The chloragogen cells also store glycogen and fat so are **analogous to liver** of the vertebrates.

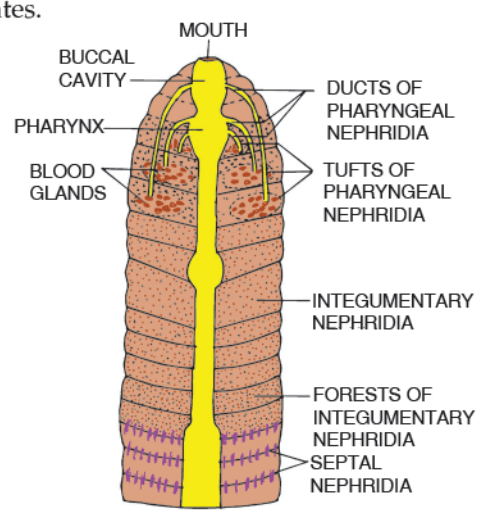


Fig. 58 Alimentary canal of earthworm.

Structure of septal nephridium (Fig. 59). It is formed of **four parts : (i) Ciliated funnel** having an aperture, **nephrostome,** through which wastes and some coelomic fluid enter the nephridium. **(ii) Neck** which connects with body. **(iii) Body** is formed of smaller straight lobe and longer spirally-twisted lobe, **(iv) Terminal duct** which leaves the nephridium.

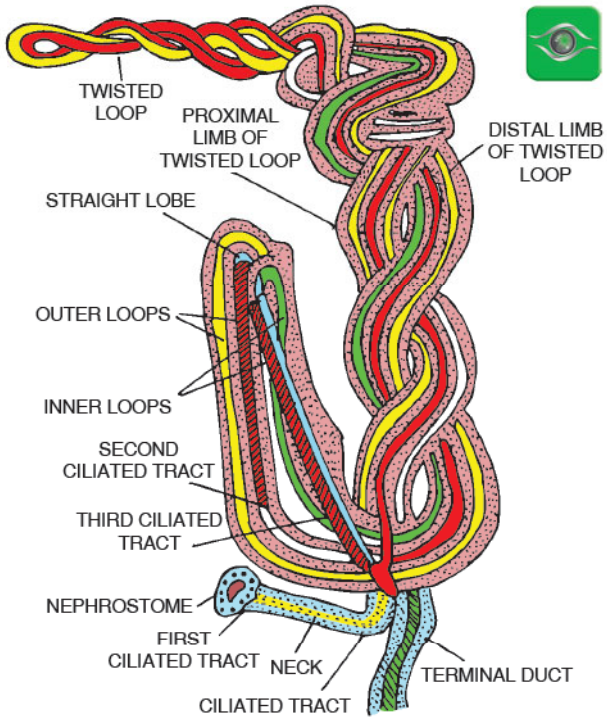


Fig. 59. *Pheretima* : A septal nephridium.

Earthworm is both ammonotelic and ureotelic in excretion. It is **ammonotelic** in excretion when plenty of water is available but is **ureotelic** (as with 50% urea, 40% ammonia and creatinine) in moist conditions. Excretion through gut is an adaptation for conservation of water. These are also **osmoregulatory** in function so regulate volume and composition of body fluids.

5. Circulatory system (Fig. 60)

Earthworm has a **closed circulatory system.** It is formed of :

(i) Blood of earthworm is formed of a red-coloured **plasma** (as iron-containing red coloured **erythrocruorin**

Table 30. Differences between Three Types of Nephridia.

Characters	Pharyngeal nephridia	Integumentary nephridia	Septal nephridia
1. Position	Found in 3 pairs of groups, one pair in each of 4th, 5th and 6th segments on the sides of the gut.	Found in all the segments except first two segments and attached to the body wall.	Found in all segments from 15th segment onward and are attached on septa.
2. Number	Not fixed.	200–250 per segment except 2000–2500 in each clitellar segments.	80 – 100 per segment.
3. Type	Closed type (no nephrostome).	Closed type.	Open type (with nephrostome).
4. Terminal ducts	Open either in buccal cavity or pharynx so called **enteronephric.**	**Ectonephric.**	**Enteronephric** (open in intestine).

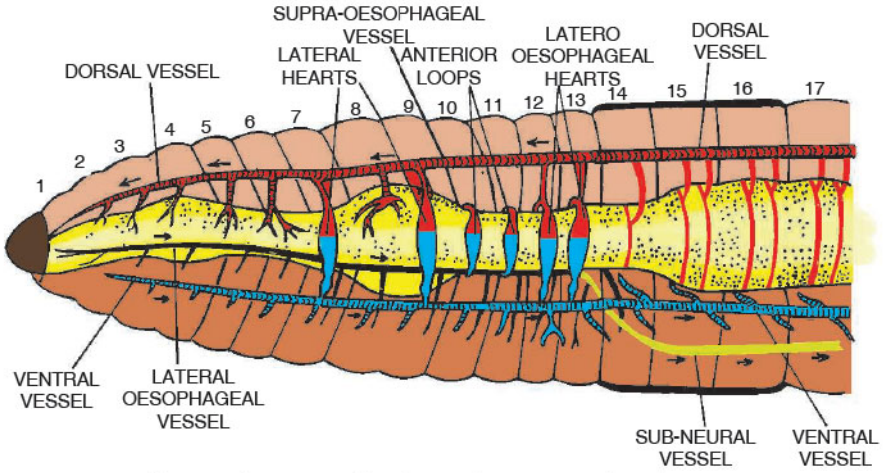


Fig. 60. *Pheretima* : Blood vascular system of earthworm.

is dissolved in it) and colourless, amoeboid and nucleated **leucocytes** (act as phagocytes).

(ii) Blood vessels. These are of following types :

(a) Dorsal vessel. It is the only thick, muscular and contractile vessel. It is present dorsal to gut through the whole length of body, so is **largest sized vessel**. Blood flows forward in it. It acts as **collecting vessel** (posterior to 13th segment) as well as **distributing vessel** (in anterior 13 segments).

(b) Ventral vessel. It is thin, non-muscular and non-contractile vessel present below the gut from 2nd to last segment. Blood flows backward in it. It acts as a **distributing vessel.**

(c) Subneural vessel. It lies below the nerve cord from 14th to last segment. Blood flows backward in it. It acts as a **collecting vessel** from the nerve cord and ventral body wall. It sends the collected blood to dorsal vessel through commissural vessels.

(d) Latero-oesophageal vessels. These are two vessels formed by division of sub-neural vessel in 14th segment. These extend upto 2nd segment and act as **collecting vessels** and collect the blood from buccal cavity, pharynx, oesophagus and the body wall.

(e) Supra-oesophageal vessel. It lies dorsal to stomach from 9th to 13th segment. It acts as **collecting vessel** and collects blood from latero–oesophageal vessels, gizzard and stomach.

(f) Lateral loops. These are two pairs (one pair in each of 10th and 11th segment) and conduct the blood from latero-oesophageal vessels to supra-oesophageal vessel.

(iii) Hearts (Fig. 61). These are **four pairs** (one pair in each of 7th, 9th, 12th and 13th segment) of contractile structures which conduct blood from dorsal vessel to ventral vessel. Anterior two pairs are called **lateral hearts,** while posterior two pairs are called **latero-oesophageal hearts.** These hearts have **valves** which allow the flow of blood from dorsal vessel to ventral

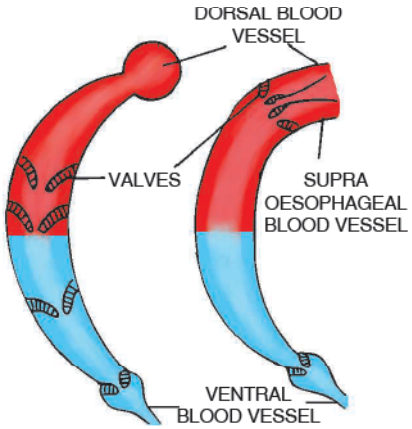


Fig. 61. Hearts of earthworm in section :
A. Lateral heart. **B.** Latero–oesophageal heart.

vessel only. Each lateral heart has four pairs of valves while each latero – oesophageal heart has three pairs of valves.

(iv) Blood glands are reddish and rounded masses of follicles present on the gut in 4th, 5th and 6th segments. These form blood corpuscles and erythrocruorin.

6. Respiration

Earthworm shows **cutaneous respiration** in which respiratory organ is skin. Skin of earthworm is thin, moist (with mucus and moisture of soil), permeable and vascular in nature so allows the exchange of environmental oxygen and carbon dioxide of blood.

7. Nervous system (Fig. 62)

Central nervous system of earthworm integrates sensory inputs as well as command muscular responses of body and is formed of **two parts :**

(i) Circum-pharyngeal nerve ring surrounds the pharynx and is formed of a pair of **supra-pharyngeal ganglia** or **cerebral ganglia** or **brain** lying dorsal to pharynx in 3rd segment, a pair of **sub-pharyngeal ganglia** below the pharynx in 4th segment and a pair of **circum-pharyngeal connectives** joining the brain with sub-pharyngeal ganglia. Each ganglion is a mass of nerve cells. Nerve ring gives nerves to first four segments.

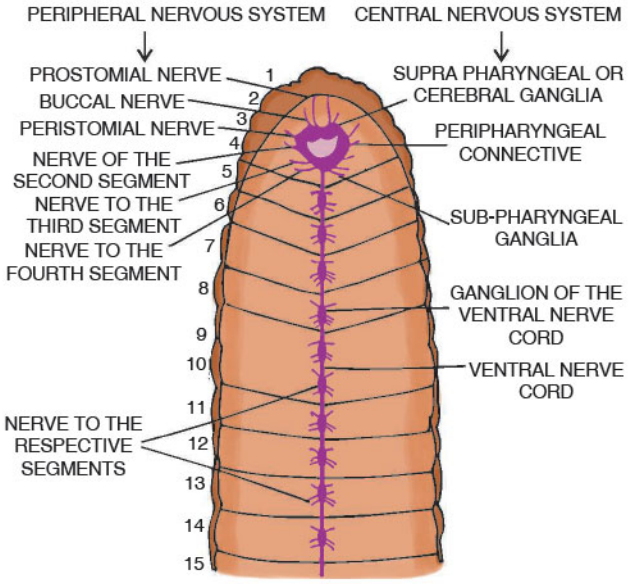


Fig. 62. *Pheretima* : Nervous system in dorsal view.

(ii) Nerve cord. It is long, solid and ganglionated which extends from 5th to last segment of body below the gut. It bears one **segmental ganglion** in each segment which gives 3 pairs of nerves. It is actually double but appears single as two nerve cords are surrounded by a common sheath.

8. Sense organs (Fig. 63)

Sense organs of earthworm are poorly developed and are formed of single or group of sensory cells called **receptors** *e.g.* **epidermal receptors** (present in groups in epidermis, tactile and chemoreceptors), **buccal receptors** (act as **chemoreceptors** and present in groups in buccal cavity lining, and are **olfactory** (smell) and **gustatory** (taste) in function) and **photoreceptors** (also called **phasosomes**) (singly in the epidermis of prostomium and peristomium and note the changes in light intensity). These sense organs are located on the anterior part of the worm.

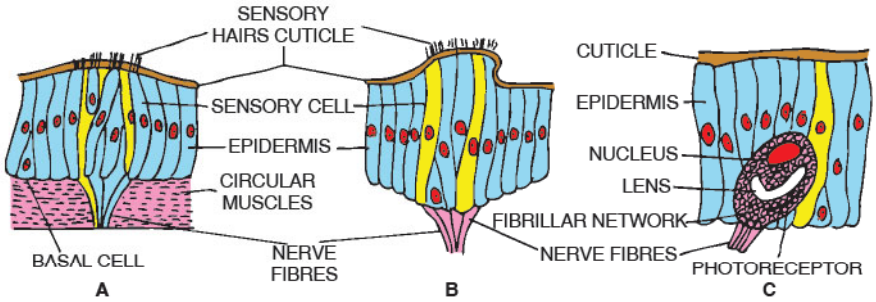


Fig. 63. Receptors of *Pheretima* : **A.** Epidermal; **B.** Buccal; **C.** Photoreceptor.

9. Reproductive system (Fig. 64)

Earthworm is **hermaphrodite** or **bisexual** or **monoecious** (testes and ovaries present in same animal) but always shows **cross-fertilization** due to **protandrous condition** (testes mature earlier than ovaries) and differential position of male and female gonopores.

(i) Male reproductive system is formed of :

(a) Testes are two pairs (one pair in each of 10th and 11th segment) of minute and whitish structures. Each testis is palmate structure and is formed of a base and 5 to 8 finger–like processes which have sper- matogonia.

(b) Testes sacs. These are two in number (one in each of 10th and 11th segment) and enclose the testes and seminal funnels. Posterior testis sac is larger in size.

(c) Seminal vesicles (or septal pouches). These are two pairs (one pair in each of 11th and 12th segment) of pouches in which spermatogonia mature into sperms.

(d) Seminal funnels are two pairs (one pair in each of 10th and 11th segment) of ciliated and funnel-like which receive the sperms from seminal vesicles.

(e) Vasa deferentia. These are fine and ciliated thread-like structures which conduct sperms from seminal funnels to 18th segment. These run backwards on the sides of nerve cord along the ventral body wall.

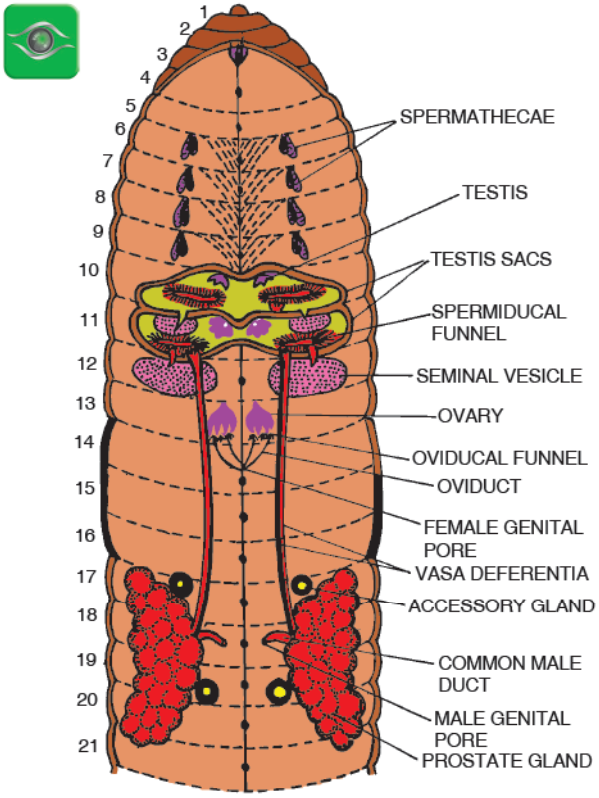


Fig. 64. *Pheretima* : Reproductive system.

(f) Prostatic duct is small sized duct of an irregular and flat **prostate gland** (present on the side of intestine from 17th to 21st segment and secretes prostatic secretion which probably provides a medium for transfer of sperms). On each side, prostatic duct joins two vasa deferentia to form a common **prostatic-spermatic duct** which opens at male gonopore.

(g) Male gonopores (Described in external morphology).

(h) Accessory glands are two pairs (one pair in each of 17th and 19th segment) of rounded glands whose ducts open at genital papillae. Their slimy secretion probably helps in keeping the two worms together during copulation.

(ii) Female reproductive system is formed of :

(a) Ovaries (Fig. 65) are one pair of minute and palmate structures attached on posterior surface of septum between 12th and 13th segment. Each ovary is formed of several finger-like processes in which ova are arranged **basipetally** in a linear manner (youngest ova at base).

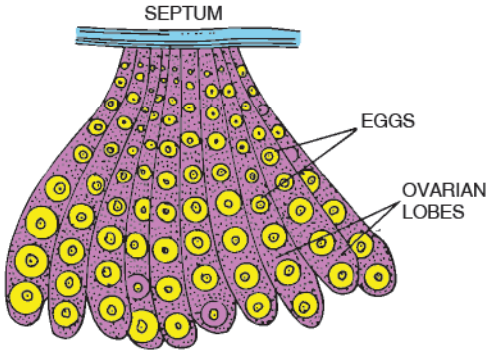


Fig. 65. Ovary of earthworm.

(b) Ovarian funnels are one pair of ciliated and funnel-like. These lie below the ovaries in 13th segment and receive ova from the ovaries.

(c) Oviducts. These are small and tubular which extend backward from ovarian funnels and join to form a common duct which opens out as female gonopore.

(d) Female gonopore (Described in external morphology).

(e) Spermathecae. These are four pairs of flask-like structures (one pair in each of 6th, 7th, 8th and 9th segment). These open out by spermathecal pores (Described in external morphology). Each spermatheca is flask-shaped and is formed of a pear-shaped **ampulla** and a short **neck**, which gives off a pouch-like **caecum** or **diverticulum** on the inner side **(Fig. 66).**

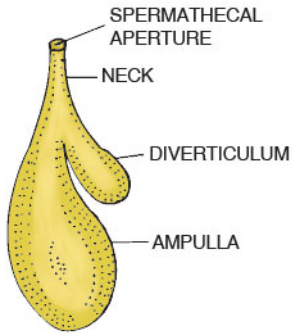


Fig. 66. Spermatheca.

(iii) Copulation and Development. Copulation occurs in earthworm during rainy season at night. Two earthworms copulate along their ventral side in **head-to-tail position** and is followed by **reciprocal cross-fertilization** (mutual exchange of bundles of sperms called **spermatophores).** Sperms are stored in spermathecae. Mature ova, stored sperms and nutritive albumen are passed in oothecae (cocoons) which are deposited in the soil. Fertilization and development occurs in **ootheca** (secreted by clitellum) and is **direct** (with no larva). Hatching occurs after about 3 weeks and on average four young ones are formed in each cocoon though their number ranges between two to twenty.

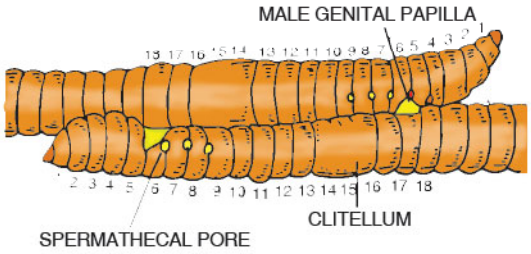


Fig. 67. *Pheretima* : Two worms in copulation.

Interaction with Mankind (Economic Importance)

Earthworm has a great economic importance and is with both useful as well as harmful activities.

1. Beneficial activities

(i) In agriculture. Earthworm is known as "**Friend of farmers**" or "**Nature's ploughman**" as it improves the soil fertility in many ways:

(a) Their habit of burrowing improves **soil aeration** which improves the respiration and penetration of roots.

(b) It carries decaying vegetations into the burrows where these form humus.

(c) These also act as **scavengers** as these also eat upon the seeds, dead leaves, eggs and larvae.

(d) It brings mineral-rich subsoil to the surface.

(e) Worm-castings and nitrogenous wastes of earthworm are of considerable manurial value. Their faeces contain nitrate, calcium, magnesium, potassium and phosphorus. Worm casts favour the germination of seeds.

(f) These reduce both acidity and alkalinity of soil.

This process of increasing soil-fertility by earthworms is called **vermicomposting.**

(ii) As food. Earthworms are used as food for **useful animals** (e.g. fishes in aquaria, some birds like robins and chickens, moles, lizards, centipedes, etc.) and also by **human beings** in countries like China, Japan, Myanmar (Burma), Australia, etc.

(iii) As bait. Earthworms are used as bait **for fishing** so have commercial advantage.

(iv) In medicines. Earthworms are also used in preparing drugs for the treatment of **bladder stones**, jaundice, piles, rheumatism, pyorrhoea, diarrhoea, etc.

(v) As **source of income** as many people are involved in their catching, multiplying and supplying earthworms to the scientific laboratories.

2. Harmful activities

(i) Due to their burrowing habit, earthworms **spoil lawns and golf grounds.**

(ii) Their burrows in the banks of the canals may cause **leakage of valuable water.**

(iii) Their burrows at slopes increase the rate of **soil erosion.**

(iv) Some species act as **pests of plants** e.g. *Pheretima elongata* damages the roots of the betaline plants and *Prionyx* earthworm damages stems of cardamom plants.

(v) Earthworms also act as **intermediate hosts** for some parasites of birds.

Due to uncontrolled use of pesticides and chemical fertilizers there is a rapid decline in the population of earthworms which is adversely affecting their predators like frogs, birds and lizards which may result an ecological imbalance.

COMPETITION PLUS

- **Dr. K.N. Bahl :** Thoroughly explained the anatomy of earthworm in a memoir.
- Dorsal surface is more darker due to **porphyrin pigment** which protects the earthworm from harmful effect of UV-radiations.
- Seta is secreted by a **seta forming cell** of setal sac.
- In *Pheretima*, setae are present in **perichaetine arrangement** i.e. in rings in the middle of the segments.
- In *Lumbricus* earthworms, each segment of body has eight setae and is called **Lumbricine** or **octachaetine arrangement**. It is an european earthworm.
- First nine septa are **complete septa** while all onward septa are **incomplete.**
- Earthworm does not have special organs of locomotion. It shows **crawling** type locomotion which is brought about by cumulative effect of body wall musculature aided by setae and hydrostatic pressure of coelomic fluid.
- Pharynx of earthworm acts as both sucking and pumping organ.
- Nephridia of earthworm are analogous to vertebrate's kidneys.
- **Metanephridium :** A nephridium having a ciliated funnel.
- **Macronephridia :** Large sized nephridia *e.g.* of *Nereis* and leeches.
- Septal nephridia are called **open-type nephridia** as have nephrostome.
- Integumentary and pharyngeal nephridia are called **closed-type nephridia** as lack nephrostome.
- **Buccal glands** are 3 pairs, embedded in pharyngeal nephridial masses in 4th to 6th segments. These manufacture blood corpuscles and haemoglobin.
- **Lymph glands** in earthworm are present on the sides of dorsal vessel from 26th segment onward. These produce phagocytes of coelomic fluid.
- Photoreceptors of earthworm are called **little eyes** or **ocelli**.
- Testes are well developed in young earthworms but degenerate in adults.
- After mating, the sperms are stored in caecum of spermatheca while ampulla provides nutrition to the sperms.
- A recent estimate suggests that nearly 250,000 earthworms may inhabit an acre of soil and may bring more than 18 tons of deeper subsoil to the surface in one year.
- **Life span** of earthworm is of 3-10 years.
- Best types of earthworms for vermicomposting are **red wrigglers** (*Eisenia fetida*) and red worms (*Lumbricus rubellus*).

PRACTICE PROBLEMS – EARTHWORM

96. What do you mean by metameres or somites?

97. Define clitellum. Give its function.

98. What are annuli?

99. What are setae? Give their function.

100. Which type of arrangement of setae is found in earthworm?
101. Differentiate peristomium and prostomium.
102. Give the location of male gonopores. What is their function?
103. What are copulatory papillae? Give their function.
104. Give the location of spermathecal pores in earthworm.
105. Why is earthworm called a hermaphrodite animal?
106. Name the masticatory part of alimentary canal of earthworm.
107. What is typhlosole?
108. Name excretory structures of earthworm.
109. How many hearts are found in earthworm?
110. Why does earthworm always show cross-fertilization?

ANSWERS TO PRACTICE PROBLEMS

96. Metameres or somites are segments of earthworm.
97. Clitellum is glandular band which surrounds 14th, 15th and 16th segments in earthworm. It secretes ootheca during breeding season.
98. Ring-like grooves which divide the body of earthworm into segments (called metameres) are called **annuli.**
99. Setae are f-shaped chitinous structures embedded in the body wall of earthworm. These help in locomotion and copulation.
100. Perichaetine arrangement (in rings).
101. First segment of earthworm is called **peristomium**, while a fleshy extension of peristomium overhanging the mouth is called **prostomium.**
102. Male gonopores lie on ventrolateral sicles of 18th segment. These transfer the sperms into spermathecae of another earthworm during copulation.
103. These are two pairs of conical ridges present one pair on each of 17th and 19th segments. Their sticky secretion keeps the copulants together.
104. These are four pairs of slit-like apertures present in the intersegmental grooves, one pair in each of between 5th and 6th; 6th and 7th; 7th and 8th; and 8th and 9th segment.
105. Earthworm is bisexual and has both testes and ovaries.
106. Gizzard.
107. A well-developed fold hanging in middle part of intestine from dorsal side. It increases surface area of digestion and absorption of food.
108. Nephridia.
109. 4 pairs (one pair in each of 7th, 9th, 12th and 13th segment).
110. Due to protandrous condition.

II. *PERIPLANETA AMERICANA* (COCKROACH)

Phylum ..... **Arthropoda** (jointed legs, sclerotized exo-skeleton, haemocoel and mouth parts)

Class ..... **Insecta** (3 pairs of legs, tracheae and one pair of antennae).

Habitat

Cockroach is a **terrestrial** and cosmopolitan insect found in places with warmth, moisture, darkness and plenty of food e.g. kitchens, grocer's shops, bakeries, railway wagons, underground drains, ships, warehouses, etc. Three species of cockroaches are found in India :

Periplaneta americana –**American cockroach** or Ship cockroach. It is largest sized and most common type.

Blatta orientalis – **Oriental** or **Indian cockroach**.

Table 31. Differences between Oriental cockroach and American cockroach.

Characters	Oriental cockroach (*Blatta orientalis*)	American cockroach (*Periplaneta americana*)
1. Colouration	Brownish-black to black coloured.	Reddish brown coloured.
2. Size	20-25 mm (smaller in size).	34-53 mm (larger in size).
3. Wings	In female, fore wings are vestigial. Hind wings are absent.	In both sexes, both pairs of wings well developed.
4. Flight	Less capacity of flying.	Good capacity of flying.
5. Ootheca	Black-coloured.	Grey coloured.
6. No. of moults	6	13

B. germanica – **German** or **Croton cockroach**. It is smallest-sized and pale yellow coloured.

Word cockroach is derived from a Spanish word – *Cucuracha.* Native place of *P. americana* is Tropical America (Mexico).

Habits

(i) Activity. It is **nocturnal** and remains hiding during daytime.

(ii) Locomotion. It is **cursorial** (fast runner) animal but also rarely flies.

(iii) Feeding. It is **omnivorous** and has biting and chewing type mouth parts.

(iv) Respiration. It shows **tracheal** respiration.

(v) Reproduction. Cockroach is **unisexual** and shows **sexual dimorphism.** Fertilization is internal and female is **oviparous.** Development occurs in ootheca and involves **gradual metamorphosis** which involves three stages: **Egg, Nymph** and **Adult (Imago).**

External Morphology — Fig. 68

(A) Shape, size colour and symmetry. The body of cockroach is elongated, dorsoventrally flattened and **oval- shaped.** It is about 34-53 mm in length and 10-12 mm in width. The colour is **reddish-brown.** Symmetry is **bilateral.**

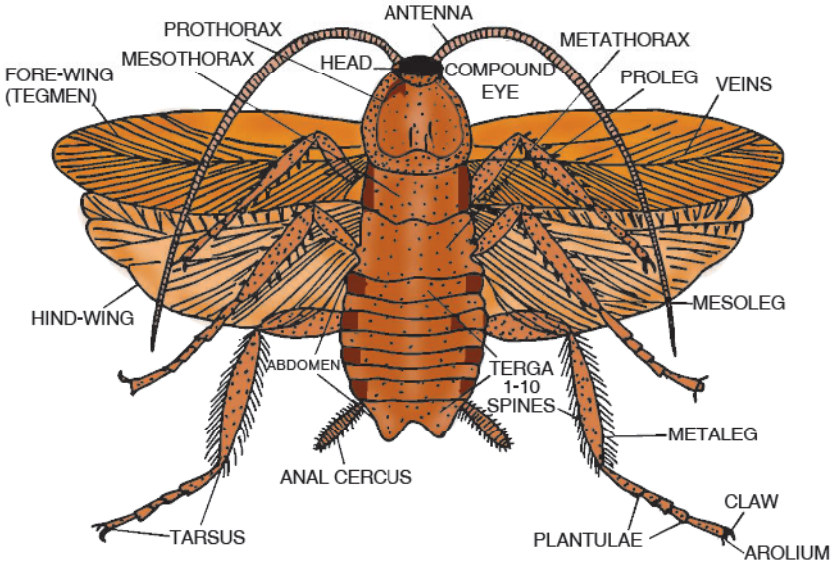


Fig. 68. *Periplaneta* (Female) : External features in dorsal view.

(B) Exoskeleton or cuticle. Cockroach is externally covered by a non-living, brown-coloured, chitinous exo-skeleton composed of several **plates** or **sclerites** which are joined by thin and flexible **arthrodial** or **articular membranes** to allow movements.

Significance. 1. Cuticle protects the body from loss of water and provides surface for attachment of muscles.

2. It also lines tracheae and genital ducts.

3. Cuticle also lines foregut as well as hind gut.

4. It forms stiff and immovable **spines** or **bristles.**

(C) Body divisions

Body of cockroach is divided into **three regions** (tegmata) :

(i) Head, (ii) Thorax, (iii) Abdomen.

(i) Head (Fig. 69)

The head is small, triangular and **hypognathous** (mouth parts are directed downwards). It is at right angle to the longitudinal axis of the body. It is attached to the thorax by a narrow and flexible **neck** or **cervicum** (extension of prothorax) so is highly movable in all directions.

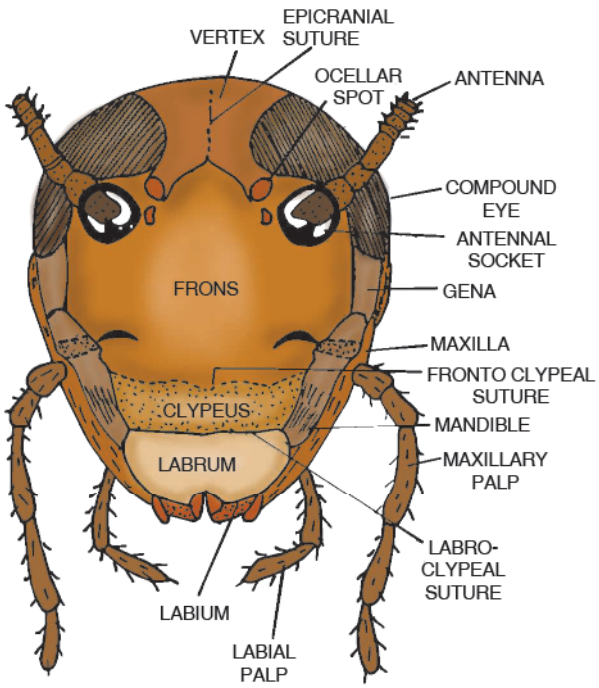


Fig. 69. *Periplaneta* – Head : Anterior view.

(a) Exoskeleton of head. Six **sclerites** of the head are fused together in the adult forming a strong **head capsule** or **cranium**. The six sclerites of head capsule are: **vertex, frons, clypeus, labrum** and a pair of cheek sclerites called **genae**.

(b) Appendages of head: (i) Compound eyes: These are one pair of large, sessile, black and **reniform** (*i.e.* kidney-shaped) **compound eyes** one on each dorsolateral side of head. Each is formed of about 2,000 visual units, called **ommatidia.** These are **photoreceptors.**

(ii) Antennae (Fig. 70). These are one pair of long, jointed and cylindrical filiform filstructures movably attached in the **antennal sockets** inner to compound eyes. Each antenna is formed of basal **scape**, middle **pedicel** and long and jointed **flagellum** with sensory bristles. These are **olfactory** and **tactile** in function. These belong to second segment of head.

(iii) Fenestrae or ocellar spots. These are one pair of rounded and whitish degenerated ocelli called **fenestrae** present inner to antennal sockets.

(c) Mouth parts (Fig. 71): These are the head appendages which surround the mouth. The mouth parts help the cockroach in "**biting and chewing**" its food (**mandibulate or orthopterus type**).

1. Labrum. Labrum, also called **upper lip**, is a broad, movable, rectangular and notched plate. Its inner surface has gustatory (taste) lining called **epipharynx.** It serves to hold the food.

2. Mandibles. These are one pair of highly sclerotized triangular structures present one on each lateral side of head. Lower part of inner margin is called **molar area** and has seven teeth-like denticles while its soft upper edge is called **prostheca**. These are **masticatory** in function. These belong to fourth segment of head.

3. First maxillae. These lie below the mandible. Each maxilla is **biramous.** First maxilla is formed of **cardo, stipes, lacinia, galea** and a 5-segmented **maxillary palp** with sensory bristles. These hold the food particles during mastication as act as **accessory jaws.** They also serve to clean antennae and forelegs. These belong to fifth segment of the head.

4. Labium or Second maxillae. Labium is a broad plate and forms the posterior margin of pre-oral cavity, so is called **lower lip.** It is formed of **mentum, submentum, prementum, glossae, paraglossae** and two three-segmented **labial palps** with sensory bristles. Labium prevents falling of food particles and pushes the food in the mouth. These belong to sixth segment of the head.

5. Hypopharynx. It is also called **lingua** or **tongue.** It is a tongue - like structure hanging in pre-oral cavity between the mouth parts. It has opening of common salivary duct at its base. It mixes the food with saliva.

Between the mouth parts of cockroach, there is a small space, called **pre-oral cavity or cibarium.**

(ii) Thorax

The middle region of body or **thorax** consists of three distinct segments : the anterior **prothorax**, the middle **mesothorax**, and the last **metathorax.** The three thoracic segments are covered by larger sclerites, called **nota** or **terga.** The notum of prothorax, called **pronotum,** is very large and covers the neck. Each segment has a smaller plate, the **sternum,** ventrally and two lateral sclerites called **pleura.** Four sclertites of each segment and sclerites of adjacent segments are joined by thin and flexible **arthrodial membranes.**

Thoracic appendages. Thorax bears two types of appendages : **Walking legs** and **wings.**

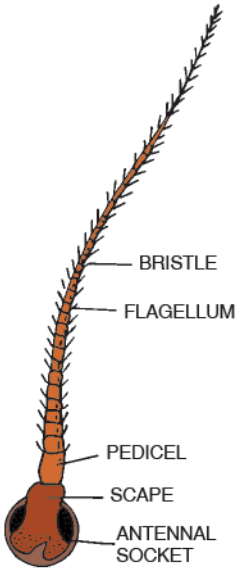


Fig. 70. *Periplaneta :* Antenna.

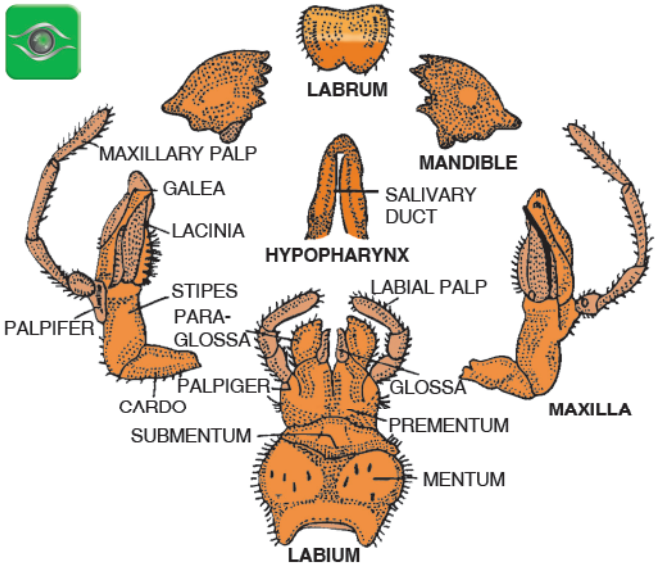


Fig. 71. Mouth parts of cockroach.

1. Walking legs (or **Pleopods**). Thorax bears 3 pairs of walking legs, one pair attached to each thoracic segment and are called **prolegs, mesolegs** and **metalegs,** so placed in class **Hexapoda.** These help in its **cursorial** and climbing habits. All the legs are similar in structure while size of legs increases posteriorly **(Fig. 72).**

Each leg is formed of five joints, the **podmeres:** stout flattened, basal **coxa**, followed by a smallest and triangular **trochanter.** The latter is fused to a long, thick, strongest and spiny **femur,** followed by a slender spiny and **longest tibia**, and a distal **tarsus** which itself is formed of 5 segments called **trasomeres.** The distal tarsomere is called **pretarsus.** It ends into a hook-like claw on each side of a adhesive pad called **arolium** or **pulvillus.** A similar adhesive pad, called **plantula,** is located at end of each tarsomere. All pads help the cockroach in climbing up smooth walls, doors etc.

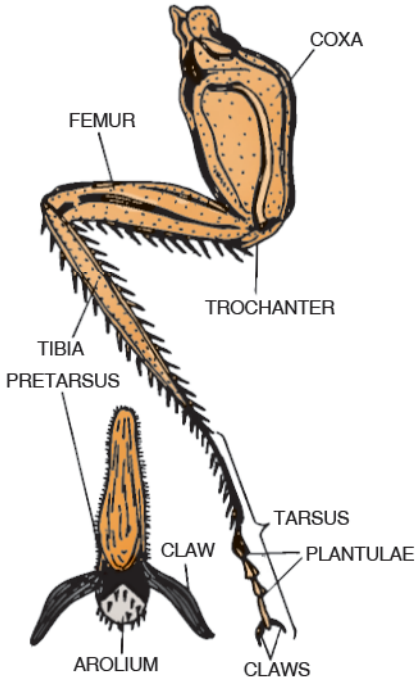


Fig. 72. *Periplaneta* : A leg and its pretarsus.

2. Wings (or **Paraeopods**). Cockroach has two pairs of **wings** or **pareopods.** Each wing is the cuticular outgrowth of the body wall and is supported by a network of branched tubules, called **nervures** or **veins,** which have haemolymph, tracheae and nerve fibres.

(a) Mesothoracic wings or fore wings. These are anterior pair of thick, leathery and opaque wings. These are not used in flight but are protective to hindwings at rest, so are called **wing cover** or **elytra** or **tegmina** (Fig. 73 A).

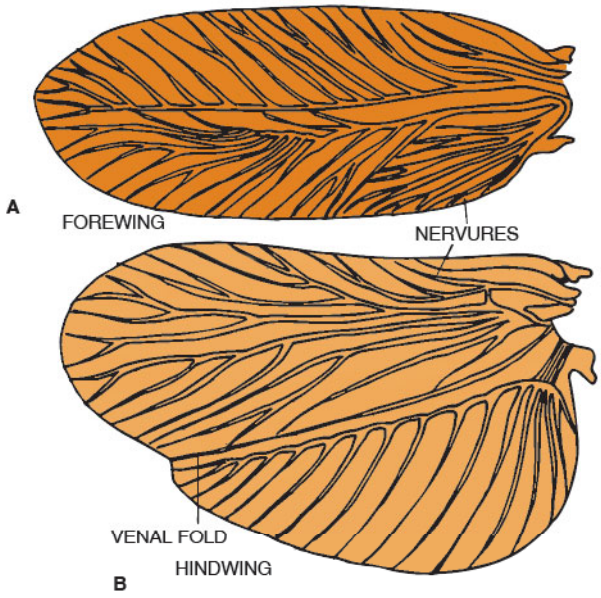


Fig. 73. *Periplaneta* : **A.** Fore wing. **B.** Hind wing.

(b) Metathoracic or Hind wings. These are posterior pair of broad thin and membranous wings **(Fig. 73 B).** They are used in flight. When not used, these are folded like japanese fans below the fore wings.

Thorax also has two pairs of **thoracic spiracles** (Explained ahead).

(iii) Abdomen. The posterior region of body is called **abdomen.** In cockroach **abdomen is long and narrow in male but is short and broad in female.** Abdomen of cockroach is formed of 10 segments.

1. Sclerites. (a) Terga. There are **ten terga. In male, seventh tergum covers 8th tergum while in female 7th tergum covers 8th and 9th terga (Fig. 74).** 10th tergum is larger in size and notched in both the sexes.

(b) Sterna. In male, all nine sterna are visible while in female only seven sterna are visible. 7th, 8th, and 9th sterna form brood or genital pouch in female. 7th sternum in female is boat-shaped and is divided into two **gynovalvular plates** or **apical lobes or genital.** Tenth sternum is absent in both the sexes.

2. Appendages (Fig. 74) In cockroach, abdomen bears **three types** of appendages :

(a) Anal cerci. These are one pair of 15–jointed structures with sensory bristles in both the sexes. These arise from 10th segment. These are **tactile** and **auditory** (hearing).

(b) Anal styles. These are one pair of unjointed, needle-like structures which arise from 9th sternum **in only male cockroach.** Anal styles help in **copulation.**

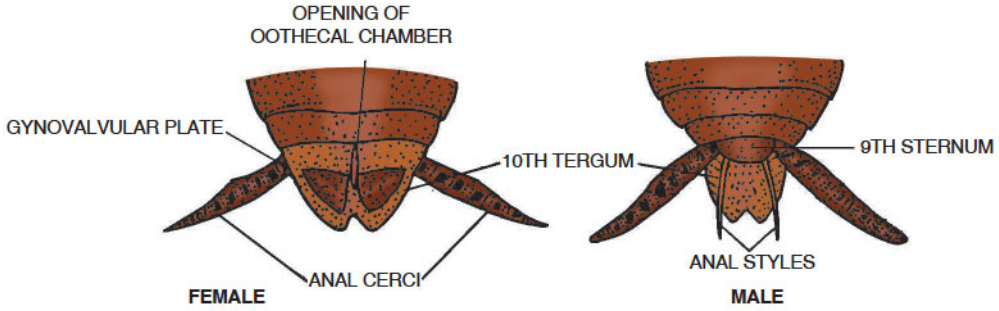


Fig. 74. *Periplaneta* : Posterior region of abdomen (Ventral view).

(c) Gonapophyses or External genitalia. These are irregular, chitionous processes around the genital aperture. In male, these are three in number while in female, these are three pairs. They act as **external genital organs in male, while ovipositor in female.**

3. Apertures.

(a) Anus. It is a slit-like aperture between 10th tergum and 9th sternum. It is bounded by 2 **podical plates** or **paraprocts.**

(b) Genital aperture. In male cockroach, the gonopore lies at the base of ventral phallomere below the anus. In female cockroach, the gonopore lies on 8th sternum.

Abdomen has 8 pairs of respiratory openings called **spiracles**.

SEXUAL DIMORPHISM IN COCKROACH

In cockroach, male and female cockroach are separate (called **unisexual**) and show **sexual dimorphism** (externally different) (Table 32).

Table 32. Differences between Male and Female cockroach.

Characters	Male cockroach	Female cockroach
1. Abdomen	Long and narrow.	Short and broad.
2. Sterna	All nine sterna visible.	Seven sterna visible.
3. Anal styles	Present.	Absent.
4. Terga	7th tergum covers 8th tergum.	7th tergum covers 8th and 9th terga.
5. Brood pouch	Absent.	Present.
6. Antennae	Longer in size.	Smaller in size.
7. Wings	Extend beyond the tip of abdomen.	Extend upto the end of abdomen.

Internal Morphology

1. Body wall (Fig. 75)

Body wall of cockroach is formed of :

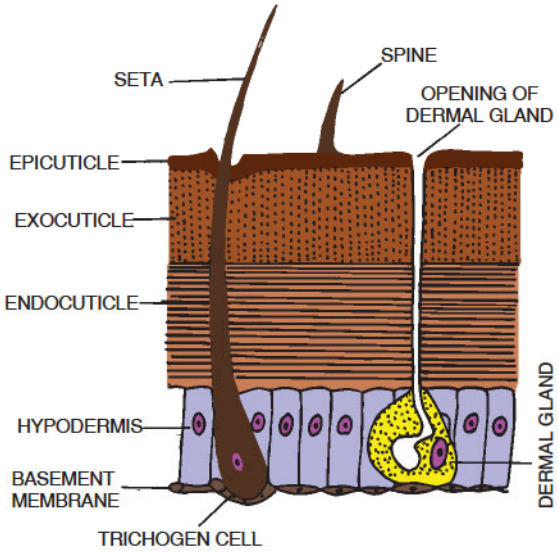


Fig. 75. *Periplaneta* : V.S. Body wall.

(i) Cuticle. It is outermost, thick, hard and non-living coat. It is differentiated into three zones : outer, thinner and waxy **epicuticle**; middle chitinous **exocuticle**; and inner thickest and chitinous **endocuticle**. It is impermeable to water so conserves the body water. It also forms immovable and tactile **spines**. It is **chitinous** in nature.

(ii) Hypodermis or Epidermis. It is a single-layered columnar epithelium. Some cells of hypodermis are modified into **dermal glands** and **trichogen cells** which respectively secrete cuticle and sensory setae.

(iii) Basement membrane. It is innermost layer of flat cells on which hypodermis rests.

Functions. It forms **protective exoskeleton** and give **definite shape.** It also helps in respiration (lines tracheae), feeding (forms mouth parts), locomotion (forms wings and legs), reproduction (forms gonapophyses), water-proofing (protects from desiccation) etc.

2. Coelom

Cockroach is **eucoelomate** and **schizocoelomate** but true coelom is reduced around the gonads, and is replaced by a pseudocoel with blood called **haemocoel**.

3. Alimentary Canal (Fig. 76)

Alimentary canal of cockroach is long, coiled, tubular and **complete.** It is formed of :

(i) Foregut or Stomodaeum. It is lined with cuticle and is formed of following parts :

(a) Mouth is a slit-like aperture and lies at the top of preoval cavity. It is surrounded by biting and chewing type mouth parts. It is for **ingestion.**

(b) Pharynx is narrow and tubular.

(c) Oesophagus is thin-walled, narrow and tubular. It extends through neck.

(d) Crop or ingluvius is a large-sized sac present in thorax and first two abdominal segments. It stores the food.

(e) Gizzard or Proventriculus is thick-walled, muscular and conical bulbous structure and is differentiated into 2 parts :

• Anterior **armarium** with six chitinous plates, called **teeth,** and six-cushion-like pads, called **pulvilli,** which bear backward directed bristles. Teeth masticate the food while bristles of pulvilli form a **strainer** which allows only fine food particles to pass.

• **Stomodeal valve** is posterior tubular part which projects into the midgut to prevent backflow of food.

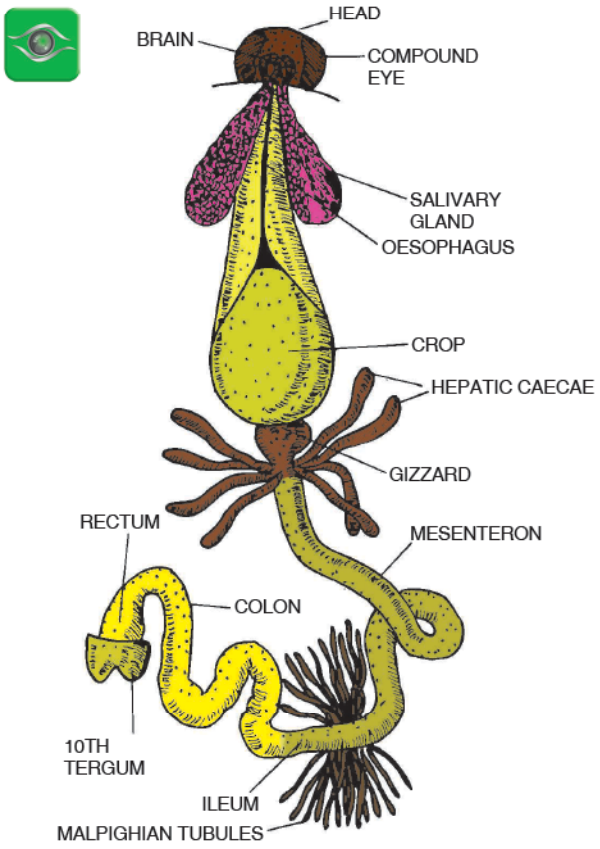


Fig. 76. *Periplaneta* : Alimentary canal and salivary apparatus.

(ii) Mesenteron or **Ventriculus** or **Midgut**. It is longest part and is thin-walled, narrow and tubular. It is glandular and is without cuticle. From its anterior end, there arise a ring of 6 to 8 finger-like outgrowths, called **hepatic** or **gastric caecae,** and secrete digestive enzymes.

(iii) Hind gut or proctodaeum. It is internally lined with cuticle and is formed of 3 parts :

(a) Ileum. It is small-sized, narrow, thin walled and tubular. At the junction of midgut and hind gut, there arise 100–150 yellow-coloured thread-like excretory **Malpighian tubules.** These are excretory in function.

(b) Colon. It is wider and coiled part and reabsorbs water and minerals.

(c) Rectum is small and dilated chamber which temporarily stores the faeces. It has 6 **rectal papillae** for absorption of water and minerals.

(d) Anus (Described in external morphology).

Digestive glands include one pair of **salivary glands** (one pair of whitish glands one on either side of crop in the thorax. Each is formed of 2 **parts :** sac-like **reservoir** and a bipartite **glandular part.** These secrete **saliva), hepatic caecae** and **midgut epithelium.**

Feeding. Cockroach is **omnivorous** and eats upon all kinds of animal and vegetable food including wood, bread, leather, paper, cloth, vegetables, fruits and even other insects and cockroaches. Food is captured, masticated and ingested with the help of mouth parts. Digestion is **intercellular** and aided by digestive juices of digestive glands. It is started in pre-oral cavity and partially digested in the crop. Food is masticated and filtered by the gizzard. Digestion is completed in mesenteron where absorption also occurs. In midgut, food is surrounded by a thin and chitinous **peritrophic membrane** (secreted by cardia of mesenteron) which is permeable to both digestive juices and digested food. It is secreted by stomodeal valve and protects the midgut lining. Undigested food is expelled as solid pellets as water is absorbed by colon and rectum.

4. Respiratory system

Cockroach shows **tracheal respiration** as respiratory structures are ectodermal, branched and silvery-white air tubes, called **tracheae,** whose external openings are called **spiracles** or **stigmata.**

Spiracles. In cockroach, there are 10 pairs of sphincter ed apertures called **spiracles** out of which two pairs are **thoracic spiracles** (one pair in mesothorax and one pair in metathorax) and 8 pairs are **abdominal spiracles** (one pair in each of first 8 abdominal segments present on the lateral sclerites, the **pleura**). Mesothoracic spiracles are largest sized. Each spiracle **(Fig. 77)** leads into an **atrium** from which a main tracheal trunk starts. The atrium has a valve and a filtering apparatus formed of bristly plates which check the entry of dust particles, water, etc. The spiracles act as **valvular apertures** to prevent loss of water and to regulate the air flow. There

are three pairs of longitudinal tracheal trunks, (1 pair of each of dorsal, ventral and lateral tracheal trunks) which are interconnected by transverse tracheae.

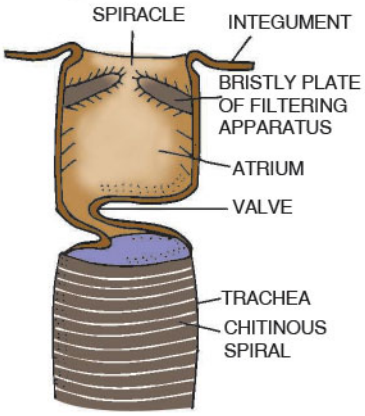


Fig. 77. *Periplaneta* : Spiracular apparatus.

Tracheal intercom (Fig. 78). Each trachea divides and redivides to form a fine network, called **tracheal intercom.** The finest branches of this intercom are called **tracheoles** which are intracellular structures and end directly into the body cells. Terminal parts of the tracheoles are filled with a tissue fluid called **tracheolar fluid** in a resting cockroach. The trachea and its branches except tracheoles are lined by a spiral cuticular lining called **taenidia** or **intima** which prevents their collapsing.

Working. In cockroach, the muscles responsible for the respiratory movements are **abdominal muscles (tergosternal muscles).** When the abdominal muscles relax, the air is drawn into tracheal system and finally diffuses through the tracheolar fluid to reach the cells. When the abdominal muscles contract, then the air with some CO_2 is forced out *via* the spiracles as most of

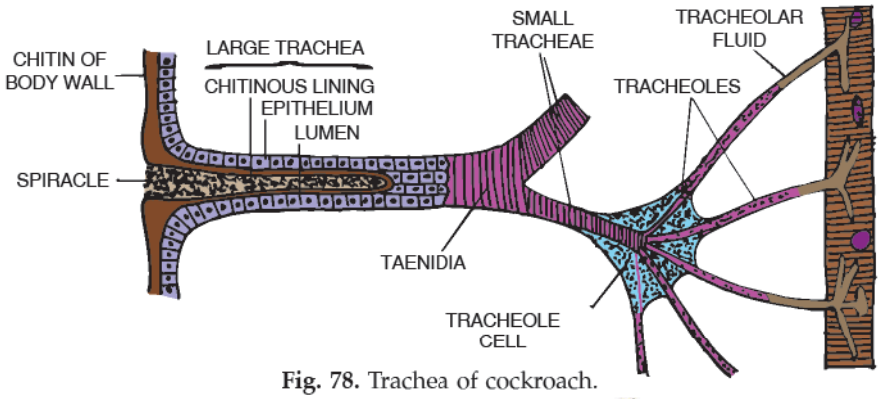


Fig. 78. Trachea of cockroach.

CO_2 produced is lost through the permeable cuticle. Thus in cockroach, **inspiration is a passive process while expiration is an active process.**

The respiratory system of cockroach is more efficient than that of earthworm as tracheal intercom directly comes in contact with the body tissues and the blood has no role in respiration.

5. Circulatory system

Circulatory system is of **open or lacunar type.**

It is formed of :

(i) Blood. It is colourless as has no haemoglobin so is also called **haemolymph.** It is formed of a transparent liquid, called **plasma**, and numerous corpuscles called **haemocytes.** Blood corpuscles are of two types: circular **proleucocytes** and amoeboid **phagocytes.**

(ii) Haemocoel. It is a **pseudocoel with blood.** In thorax and abdomen of cockroach, it is divided into 3 interconnected chambers : **Dorsal or pericardial sinus** (enclosing the heart), **middle** or **perivisceral sinus** (lodging various visceral organs) and **ventral** or **perineural sinus** (enclosing the nerve cord) by two perforated partitions, called **diaphragms.**

(iii) Heart (Fig. 79). Heart of cockroach is elongated, thick, muscular, **tubular and 13-chambered** (each chamber represents one heart). It lies in pericardial sinus of

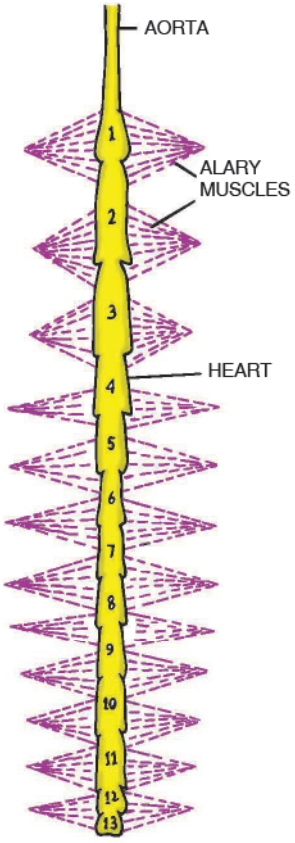


Fig. 79. *Periplaneta* : Heart.

the haemocoel. Each chamber of heart receives oxygenated blood from the dorsal sinus through one pair of slit-like apertures, called **ostia,** which are **valvular apertures (Fig. 80).** Heart contracts postero-anteriorly at the rate of about **100-200 times/minute** so the blood also flows postero-anteriorly. Muscles responsible for blood circulation in cockroach are **alary muscles,** (12 pairs), one pair in each segment, one on either side of heart. Pointed ends of alary muscles are attached to the terga. First chamber leads into an aorta which opens in **head sinuses** which are connected to pericardial sinus through perineural and perivisceral sinuses.

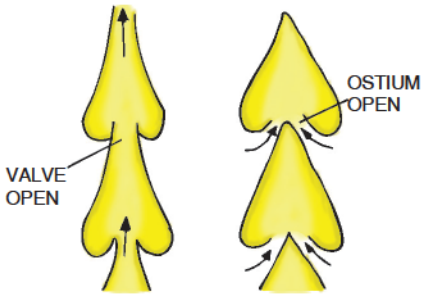


Fig. 80. *Periplaneta* : Two chambers of heart to show ostia.

Blood circulation in cockroach **(Fig. 81)** is completed in **20–30 minutes.**

Heart ⟶ Aorta ⟶ Head sinuses
↑ ↓
Pericardial sinus ⟵ Perivisceral sinus ⟵ Perineural sinus

Fig. 81. Blood circulation in cockroach.

6. Excretory organs

Main excretory and osmoregulatory organs of cockroach are **Malpighian tubules (Fig. 82).** These are fine, yellow-coloured, unbranched, thread-like structures present at the junction of midgut and hind gut (ileum) and hang freely in the haemocoel. These are about 100–150 in number and are present in 6–9 groups.

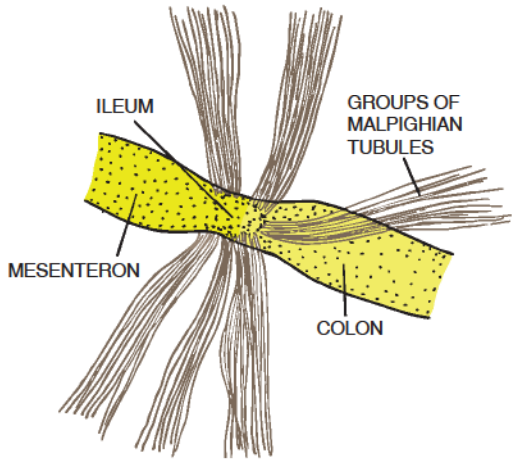


Fig. 82. *Periplaneta* : Malpighian tubules.

Each Malpighian tubule is lined by a single layered ciliated cuboidal glandular epithelium having **microvilli (brush–border).** These absorb the nitrogenous wastes from the haemolymph and transform them in uric acid which is expelled out through gut. So cockroach is **uricotelic** in excretion. Excretion through gut is an adaptation for conservation of water.

Other excretory structures in cockroach are : **urate cells** of fat bodies (excretion by storage as these store uric acid and urate granules), **nephrocytes** or **pericardial cells** (found in the pericardial cavity around the heart. These absorb excretory matter and then deposit them beneath the cuticle and is lost during moulting or ecdysis), **cuticle** and **uricose glands** (at the periphery of mushroom shaped gland of male cockroach. These extract the uric acid, store it and discharge it over the spermatophore during copulation).

7. Central Nervous system (Fig. 83)

Central nervous system of cockroach is formed of **two parts :**

(i) Circum-oesophageal nerve ring. It surrounds the oesophagus and is formed of a pair of **supra-oesophageal or cerebral ganglia** (called brain) above the oesophagus and above the tentorium in the head; a pair of **sub-oesophageal ganglia** below the oesophagus; and a pair of **circum-oesophageal connectives.** It gives nerves to antennae, compound eyes and mouth parts.

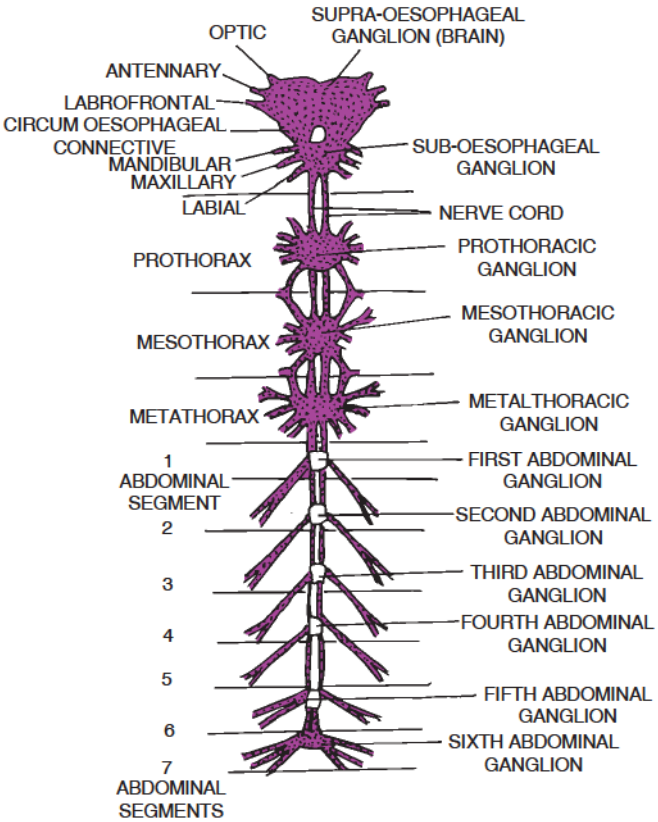


Fig. 83. *Periplaneta* : Nervous system.

(ii) Nerve cord. It is double and extends from sub-oesophageal ganglia to 7th abdominal segment below the gut. Each nerve cord bears 9 ganglia (3 in thorax and 6 in abdomen). Six abdominal ganglia die in 1st, 2nd, 3rd, 4th, 6th and 7th abdominal sagments. Sixth abdominal ganglion is larger in size as it is formed due to fusion of several ganglia. Two nerve cords are joined at the ganglia only so giving **ladder-like** appearance. These ganglia give nerves to body segments.

8. Sense organs

(i) Compound eyes. These are a pair of large-sized, sessile, black and kidney-shaped structures present on dorsolateral sides of head. Each eye is formed of about 2000 simple eyes, called **ommatidia (Fig. 84).** Each ommatidium is formed of 2 parts : **Dioptric or focussing part** formed of a corneal lens, a pair of corneagen cells, refractile crystalline cone, four cone cells and six iris pigment cells; and **receptive part** formed of a refractile rod-like rhabdome, seven photosensitive retinal cells (**retinulae**) and six retinal pigment cells.

Compound eyes of cockroach are adapted for **mosaic or apposition vision** (each ommatidium forms the image of only a part of object and a final image is formed of a number of images lying side by side). These are also adapted to detect movement of the object more efficiently but has poor resolution.

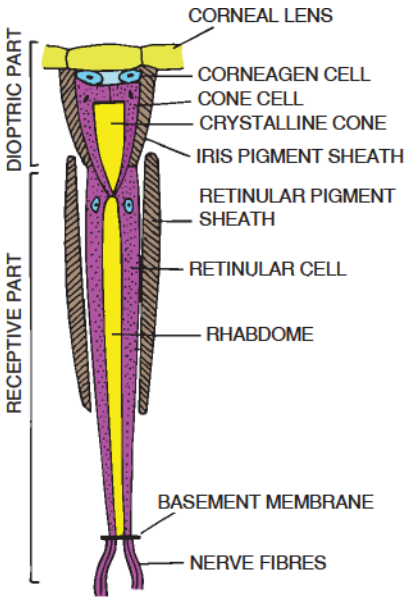


Fig. 84. V.S. of an ommatidium of compound eye of cockroach.

(ii) Sensillae. These are neurosensory cells associated with setae. These are adapted for different sensation on different body structures e.g. **tactile (touch) sensillae** (on antennae, tibiae of legs, maxillary palps and anal cerci); **auditory (hearing) sensillae** (on anal cerci only); **olfactory (smell) sensillae** (on antennae, maxillary and labial palps, etc.) and **gustatory (taste) sensillae** (on epipharynx of labrum and maxillary and labial palps).

9. Endocrine glands (Fig. 85)

These are **ductless glands** and secrete hormones. These include:

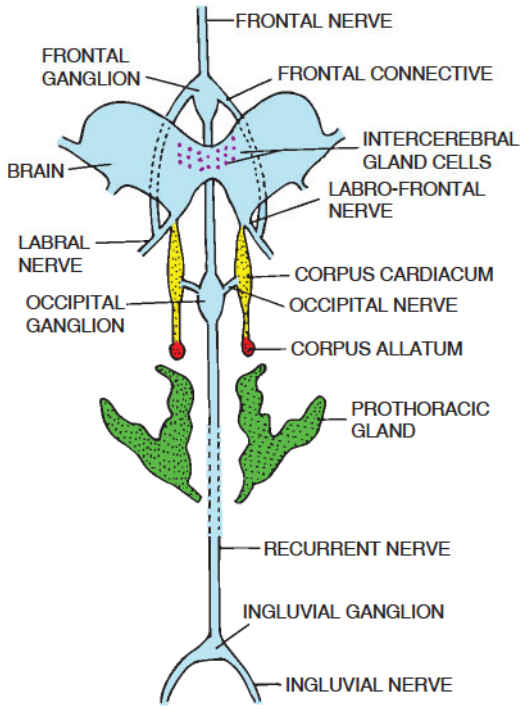


Fig. 85. *Periplaneta:* Endocrine glands.

(i) Intercerebral gland cells. These lie between the cerebral ganglia. These secrete **brain** or **prothoracic hormone** which stimulate prothoracic glands to secrete ecdysone hormone.

(ii) Prothoracic glands. These are a pair of irregular glands present in the prothorax. These secrete **ecdysone hormone** which controls **moulting** or **ecdysis** during gradual metamorphosis of nymph into adult. These degenerate in adult cockroach.

(iii) Corpora cardiaca. These are a pair of rod-shaped glands which lie on the sides of oesophagus. These secrete **growth hormone** which controls the growth of nymphs.

(iv) Corpora allata. These are a pair of small sized rounded glands present just behind the corpora cardiaca. These secrete a **juvenile hormone** which checks the appearance of adult characters. It becomes inactive during last moulting so allows the appearance of adult characters. In adult cockroach, these again become active and secrete a **gonadotrophic hormone** which regulates the functioning of gonads.-

10. Male Reproductive system (Fig. 86). It is formed of following parts :

(a) Testes are one pair of trilobed structures present in 4th to 6th abdominal segments. Each lobe is formed of 30 to 40 **follicles** in which spermatozoa are formed. These are well developed and functional in young cockroach but become non-functional in adult insect.

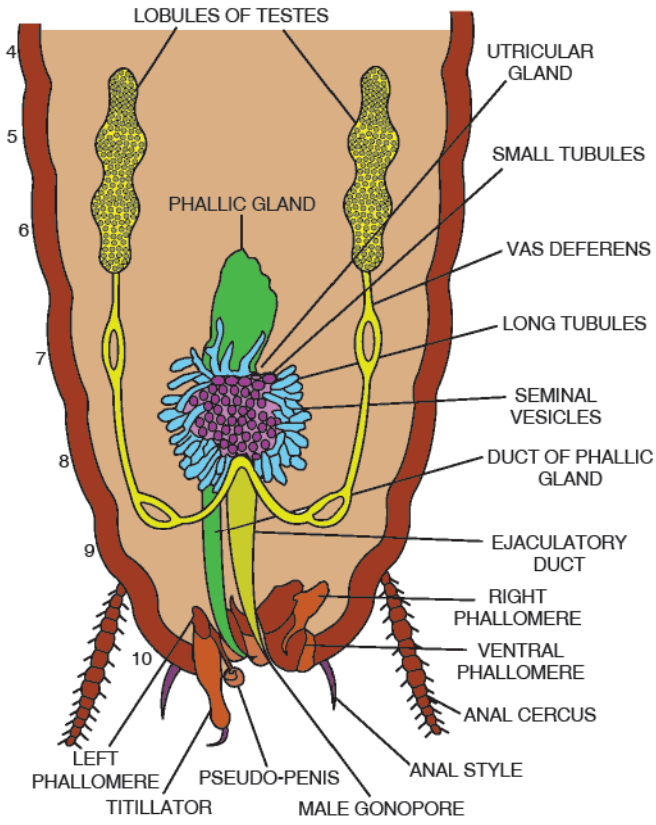


Fig. 86. *Periplaneta* : Male reproductive system in dorsal view.

(b) Vasa deferentia. These are one pair of thin and tubular structures which extend from the posterior ends of testes and open in a median ejaculatory duct.

(c) Ejaculatory duct is a wide, median, glandular and muscular duct which extends backward and opens out by male gonopore ventral to anus. It secretes middle coat of spermatophore.

(d) Mushroom or Utricular gland. It is a large-sized, whitish gland present at the junction of vasa deferentia and ejaculatory duct in 6th and 7th abdominal segment. It acts as an **accessory reproductive gland** and is formed of **seminal vesicles** (to store sperms), **small tubules** (provide nutrition to sperms) and many **large tubules** (to form innermost wall of spermatophore).

(e) Phallic or Conglobate gland is an elongated, leaf-like gland present below ejaculatory duct. Its duct opens near the male gonopore. It also forms outermost wall of spermatophore.

(f) Gonapophyses. These are three chitinous structures, called **phallomeres,** surrounding male gonopore. These act as **external genitalia** of male and help in copulation.

Sperms are formed in the testes, conducted by vasa deferentia by peristalsis, stored in seminal vesicles, and glued together as bundle in a 3-layered coat, called **spermatophore.** Its innermost coat is secreted by long tubules of utricular gland, middle coat is secreted by ejaculatory duct, while outermost coat is secreted by phallic gland **(Fig. 87).**

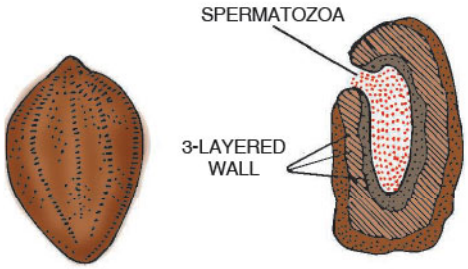


Fig. 87. *Periplaneta* : **A.** Spermatophore. **B.** Section.

11. Female reproductive system (Fig. 88). It is formed of following parts :

(i) Ovaries. These are one pair of large-sized, light yellow-coloured structures present in 2nd to 6th abdominal segments. Each ovary is formed of eight beaded tubules, called **ovarioles** or **ovarian tubules,** each containing a linear series of ova in **acropetal order.**

(ii) Oviducts are one pair of short tubular structures which start from posterior ends of ovaries, run backward and join to form **common oviduct** or **vagina.**

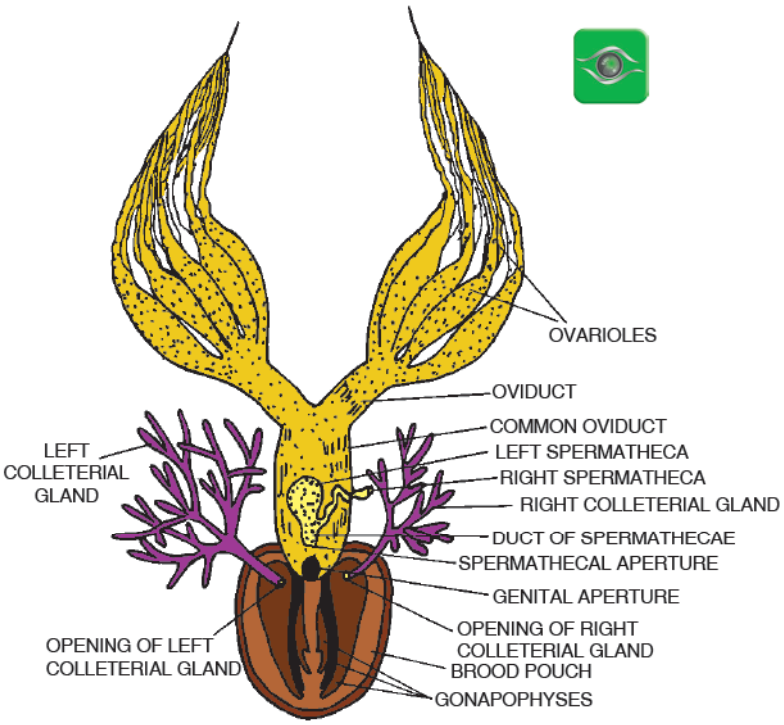


Fig. 88. *Periplaneta* : Female reproductive organs in dorsal view.

(iii) Vagina is small, muscular and tubular. It extends backward and opens in brood pouch by female gonopore on 8th segment.

(iv) Brood pouch or Genital pouch or Gynatrium. It is formed by 7th, 8th and 9th sterna of female and is divided into two parts : anterior **genital chamber** (has openings of common oviduct, spermathecae and collaterial glands) and posterior **oothecal chamber.**

(v) Collaterial glands. These are a pair of branched (left gland is more branched) **accessory reproductive glands of female** which open in genital chamber separately. Their secretion forms **ootheca.**

(vi) Spermathecae. These are a pair of unequal sized structures present in 6th abdominal segment (Right spermatheca is narrow while left spermatheca is sac-like) which open in genital chamber on a papilla. These store the sperms received during copulation.

(vii) Gonapophyses. These are three pairs of chitinous structures surrounding female gonopore. These act as **ovipositor** and arrange the ova in the ootheca.

12. Copulation, ootheca formation, fertilization and development

Male and female cockroaches copulate generally in the night during months of March to September. The process of copulation lasts for an hour or more. Male and female cockroaches meet by their posterior ends. Spermatophore is deposited near the spermathecal papilla of female by gonapophyses of male. Sperms migrate into the spermatheca while spermatophore wall is dropped.

Each ovariole forms one mature ovum at one time. Sixteen ova are conducted into genital chamber by peristalsis and arranged in two rows by 3 pairs of gonapophyses. Sperms are released from spermathecae. So fertilization is internal. Scleroproteinaceous secretion of collaterial glands is shaped into a purse-like **ootheca (Fig. 89)** by the ovipositor and is deposited at some damp and safe place. Each ootheca is dark brown to blackish-brown coloured, about 8mm. long and purse like. On an average, a female cockroach produces 9-10 oothecae, each containing 16 eggs arranged in two rows. Development is direct and life history includes 3 stages: **Egg → Nymph** (similar to adult in morphology and physiology but is smaller in size, paler in colour, wingless and sexually immature **(Fig. 90).** It undergoes **13 moulting or ecdysis** and gradual metamorphosis) → **Adult.** The wing pads are formed in next to last nymphal stage. This type of development is called **gradual metamorphosis or paurometaboly.**

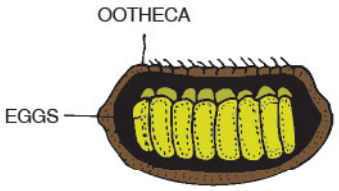


Fig. 89. *Periplaneta* : Ootheca.

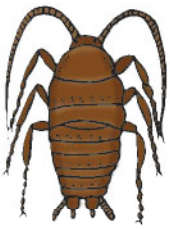


Fig. 90. *Periplaneta* : First instar.

INTERACTION WITH MANKIND (ECONOMIC IMPORTANCE)

1. Harmful activities

(i) It **damages household materials** like clothes, shoes, purses, etc.

(ii) It **contaminates the food stuffs,** befouls them so that they become unpalatable.

(iii) These also act **as vectors** for the germs of a number of diseases like cholera, diarrhoea, typhoid, etc.

2. Useful activities

(i) These are used **as food by the people** of some South American countries and Myanmar.

(ii) These are used **as food for a number of useful animal types** like amphibians, lizards, birds and rodents.

(iii) Cockroaches are used as **safe experimental animal** for laboratory experiments and biological research as these are easily available.

LEARNING PLUS

- Mandibles of cockroach can be moved horizontally by **adductor** (move closer) and **abductor** (move away) **muscles.**
- Each segment of cockroach is covered by four exoskeletal sclerites: one dorsal **tergite**, one ventral **sternite** and two lateral **pleurites**.
- **Cervical sclerites :** Four chitinous plates which support the neck.
- **Podical plates** represent 11th vestigial segment of abdomen of cockroach.
- Gonapophyses of male belong to 9th segment, while those of female belong to 8th and 9th segments.
- Cuticle of insects is hard not due to calcium salts but due to chitin protein.
- Endoskeletal elements of head and thorax of cockroach are called **apodemes** e.g. **tentorium** in the head of cockroach. These are meant for attachment of the muscles.
- Fat body of cockroach is also with **urate cells** which store uric acid waste and help in **excretion by storage**.
- Cockroach also shows **cannibalism** as eats upon the cockroaches also.
- Anterior part of mesenteron, which surrounds the stomodaeal valve, is called **cardia.**
- **Peritreme :** A ring-like sclerite which surrounds the spiracle.
- In cockroach first thoracic and first abdominal spiracles are always open, while others open during inspiration and close during expiration.
- **Pulsatile hearts :** These are two accessory hearts present at the bases of antennae. These pump the blood into the antennae.

R U CURIOUS

- Heart of cockroach is **neurogenic**.
- Alternate contraction and relaxation of the alary muscles cause the dorsal diaphragm to raise and fall.
- Haemolymph does not help in transport of respiratory gases due to absence of haemoglobin.
- Tracheoles are lined by a protein called **trachein**.
- Juvenile hormone is also called **neonitin**.
- Mushroom gland and phallic gland are accessory glands of male cockroach.
- Long-sized peripheral tubules of mushroom gland are called **utriculi majores**, while small tubules are called **utriculi breviores.**
- **Stink glands** are sac-like glands present between 5th and 6th terga of male cockroach. These produce a secretion with a peculiar odour which attracts the female cockroach.
- Eggs of cockroach and other insects are **polylecithal** and **centrolecithal** (yolk is in high amounts and located at the centre).
- The embryonic development occurs inside the ootheca and takes nearly 5 to 13 weeks.
- **Exuviae :** The moulted covering of nymph.
- **Stadium :** Interval between two moults.
- **Instar :** Nymphal stage between successive moults.
- There are 6 moults in the life cycle of *Blatta orientalis*.
- **Imago:** Final instar or adult insect.
- **Corpora adiposa** is the well-developed fat body of cockroach and is lobulated structure present in the perivisceral sinus. Each lobe is formed of trophocytes, mycetocytes, oenocytes and urate cells.
- At least 22 species of pathogenic human bacteria, viruses and protozoans and 5 species of helmenthic worms are spread by American cockroach.

PRACTICE PROBLEMS – COCKROACH

111. What are sclerites?
112. Name three body parts of a cockroach.
113. Head of cockroach is called hypognathous. Why?
114. Give another name for upper lip and lower lip of cockroach.
115. Which type of mouth parts are found in cockroach?
116. What are ommatidia?
117. Differentiate a tergum and a sternum.
118. Why are the fore wings of cockroach called tegmina?
119. Give two differences between male and female cockroach.
120. What are gonapophyses?
121. What is function of crop in cockroach?
122. Name the respiratory structures of cockroach.
123. Why does the blood of cockroach called haemolymph?
124. Name the visual units of compound eyes of cockroach.
125. What are excretory structures of cockroach?
126. Give the position of ovaries in cockroach.
127. Give the functions of mushroom gland in male cockroach.

ANSWERS TO PRACTICE PROBLEMS

111. These are chitinous plates which collectively form **sclerotized exoskeleton.**
112. Head, thorax and abdomen.
113. Mouth parts in cockroach are directed downward.
114. (i) upper lip = Labrum, (ii) lower lip = Labium
115. Biting and chewing type.
116. Visual units of compound eyes of cockroach.
117. **Tergum** is dorsal sclerite while **sternum** is a ventral sclerite.
118. These are thick, leathery and protective in function and act as **wing covers** for hind wings.

119. (i) Male cockroach has anal styles, 9 visible sterna, long sized wings and three gonapophyses.
(ii) Female cockroach has brood pouch, 7 visible sterna, and three pairs of gonapophyses.
120. These are irregular chitinous structures which surround the gonopore. These are three in male cockroach and act as **external genitalia**, while these are three pairs in female cockroach and act as **ovipositor.**
121. Crop stores the food.
122. Tracheae.
123. As it has no haemoglobin and is colourless.
124. Ommatidia.
125. Malpighian tubules.
126. In 4th, 5th and 6th abdominal segments.
127. Seminal vesicles store the sperms. Small vesicles provide nutrition to sperms. Large vesicles form wall of spermatophore.

III. *RANA TIGRINA* (FROG)

Phylum ..... **Chordata** (Notochord, dorsal and hollow nervous system, gill slits and tail).

Subphylum ..... **Vertebrata or Craniata** (Presence of vertebral column and brain box).

Superclass ..... **Tetrapoda** (Presence of two pairs of limbs).

Class ..... **Amphibia** (Amphibious habitat, cutaneus respiration, no exoskeleton, 3-chambered heart and fish–like aquatic larva in development).

Habitat : It is an **amphibious** animal found in and near the fresh-water bodies. It is commonly called **Bull frog of India** (as is largest-sized frog and has loud voice). These are very commonly seen during rainy season (it is their breeding season).

Habits : (i) Activity. It is **diurnal.**

(ii) Locomotion. It **swims** in water (with the help of webs between the toes) and **leaps** on land (so their hind limbs are longer than the fore limbs).

(iii) Feeding. It is **carnivorous** and feeds upon insects, spiders, worms, etc. Prey is captured with the help of anteriorally fixed and posteriorly free, sticky and protrusible tongue.

(iv) Hibernation (also called **winter sleep).** Frog is a **cold-blooded** or **poikilothermal** animal so frog undergoes **hibernation or winter sleep** as well as **aestivation** or **summer sleep.** During these periods, the frog depends upon the reserve food (*i.e.* fats in fat bodies and glycogen in liver cells), respires through skin and has low metabolic rate.

(v) Reproduction. Sexes are **unisexual** and show **sexual dimorphism** (Table 33). Sexual embrace or amplexus occurs in water and sex cells are released. Female is **oviparous** and eggs are laid in gelatinous mass called **sprawn** and fertilization is **external**. Development is indirect and includes a fish-like **tadpole larva** which undergoes metamorphosis.

(vi) Protective colouration or **metachrosis** or **camouflaging** i.e. change of body colour according to surroundings for defnce, is called **mimicry.**

Table 33. Sexual dimorphism in frog.

Characters	Male frog	Female frog
1. Vocal sacs	Present on ventrolateral sides of throat.	Absent.
2. Croaking	More louder.	Less louder.
3. Forelimbs	Stouter and more muscular.	Less muscular.
4. Amplexusory pads	Present on ventral side of index fingers.	Absent.
5. During breeding season	Abdomen does not change much.	Abdomen swollen as it is full of ova released from mature ovaries.

External Morphology–Fig. 91

(A) Shape, size, colour and symmetry. Frog is dorsoventrally flat and streamlined. It is about 18-20 cm in length and 5-8 cm in width. It is spotted olive green on dorsal side with irregular dark spots and pale yellow coloured on ventral side. Dorsal side also has a median and longitudinal **dorsal line** running from head to posterior end of the body. It is **bilateral symmetrical.**

(B) Body division. Frog has two body parts **(Fig. 91): (i) Head** and **(ii) Trunk.** Neck and tail are absent.

(i) Head. It is flattened and triangular. It is produced into a conical **snout** in front of nostrils. It bears following structures:

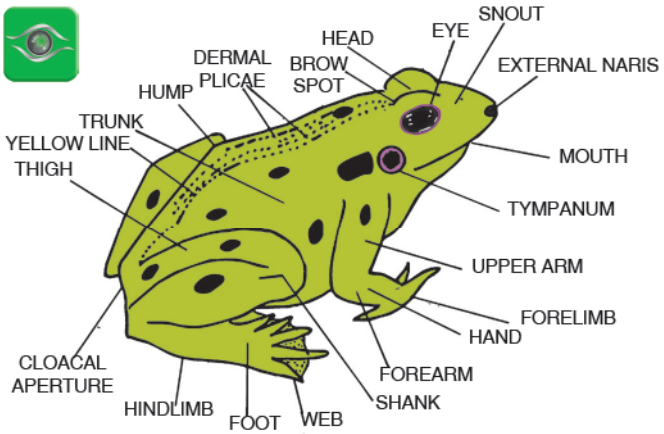


Fig. 91. External morphology of frog.

1. Mouth is terminal and wide to capture the prey.

2. Nostrils or external nares are one pair of small and circular apertures present at the tip of snout. These help in **respiration.**

3. Eyes are large-sized and spherical. These are located on dorsolateral sides of head and are bulging outward to see around even in the absence of neck. Each eye is with **three eyelids. Nictitating membrane** or **third eyelid** which protects the cornea from dust on land and mud in pond or during hibernation.

4. Brow spot is a small, circular and light-coloured spot located on mid–dorsal side between the eyes. It represents **vestigial third eye (Pineal eye).**

5. Tympanic membrane or eardrum is a small, circular and pigmented membranous skin fold and is present just behind the eye. It **receives sound signals.**

6. Vocal sacs are one pair of balloon-like distensible structures present on ventrolateral sides of throat **in male frog only**. These act as **resonators** and increase the pitch of croaking (**mating call**) of male frog.

(ii) Trunk. It has a **sacral hump** on its dorsal side just behind the middle of it. Skin of trunk has a few longitudinal folds, called **dermal plicae.** Anterior smaller and harder portion of trunk is called **thorax**, while its posterior larger and softer portion is called **abdomen**. It bears the following structures :

1. Limbs. Frog is a **tetrapod** vertebrate and bears **two pairs** of limbs :

(a) Fore limbs (Fig. 92). These are shorter and stouter. These arise from anterior part of trunk. Each is formed of 3 parts : upper arm or **brachium, fore arm** or **antebrachium**, and hand or **manus** which bears only four digits as pollex (thumb) is absent. In male frog, ventral side of first finger (**index**) has a **nuptial** or **copulatory** or **amplexusory pad (Fig. 92 A)** which becomes greatly enlarged during breeding season. These pads help the male frog to grip a female frog during **amplexus (sexual embrace).** Phalangeal formula of each fore limb is **02233**.

Fore limbs help in **directional orientation** during swimming and act as **shock absorber** during landing.

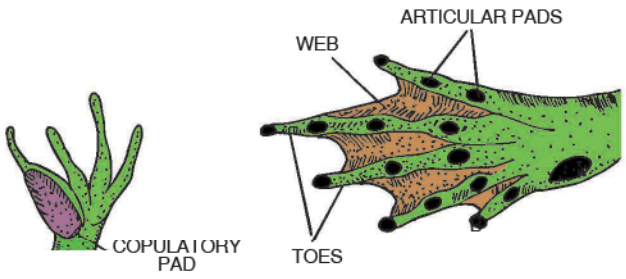


Fig. 92. Limbs of frog. **A.** Fore limb (male) **B.** Hind limb.

(b) Hind limbs. These are longer in size and arise from posterior part of trunk. Each hind limb is formed of 3 parts : upper thigh or **femur,** middle shank or **crus,** and distal foot or **pes** which bears five toes but no nails or claws. Phalangeal formula of each hind limb is **22343**. Between the toes there are skin folds, called **webs (Fig. 92B)**, which help in swimming. When at rest, three parts of hind limbs are folded in the form of "Z" and when straightened, these help in **leaping** with a jerk.

2. Cloacal aperture. It is a slit-like aperture present at the posterior end of trunk and is a common outlet of faeces, urine and sex cells (sperms and ova).

Internal Morphology

1. Skin (Fig. 93)

Skin of frog is thin, moist, naked (without exoskeleton) and smooth. It is loosely attached to body wall muscles and there are a number of **subcutaneous lymph sinuses.** It is formed of **two parts :**

(i) Epidermis. It is outer, thinner and **stratified**. Lowermost layer, called **stratum germinativum,** is a columnar epithelium. The uppermost layer, called **stratum corneum,** is formed of flat and nucleated cells and undergoes **moulting.**

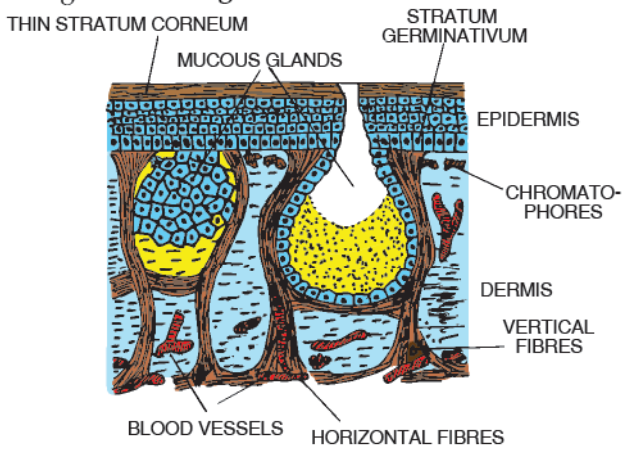


Fig. 93. V.S. Amphibian skin.

(ii) Dermis. It is inner and thicker and is formed of areolar connective tissue. It is with blood capillaries, **chromatophores** (pigment cells), bundles of white fibres (both vertically and horizontally) and multicellular and simple saccular **mucous glands.**

Functions: Skin forms protective covering of the body. Mucous glands secrete mucin which keeps the skin moist for respiration. Water is absorbed through skin. Pigment cells help in camouflaging.

2. Coelom (Body cavity)

Frog is **eucoelomate** and **enterocoelomate**. It is divisible into two parts: anterior smaller **pericardial cavity** around the heart; and posterior larger **pleuroperitoneal cavity** surrounding the lungs and other visceral organs.

3. Alimentary canal (Fig. 95)

Alimentary canal of frog is long, coiled, tubular and **complete.** Due to carnivorous feeding, intestine of frog is small-sized than that of herbivores *e.g.* rabbit. It is formed of:

(i) Mouth. It is terminal and wide (due to carnivorous diet).

(ii) Buccopharyngeal cavity is with following structures **(Fig. 94)**:

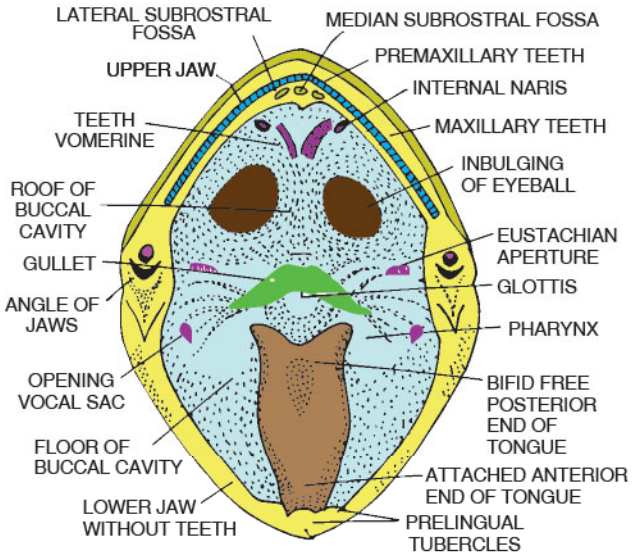


Fig. 94. Frog : Buccopharyngeal cavity.

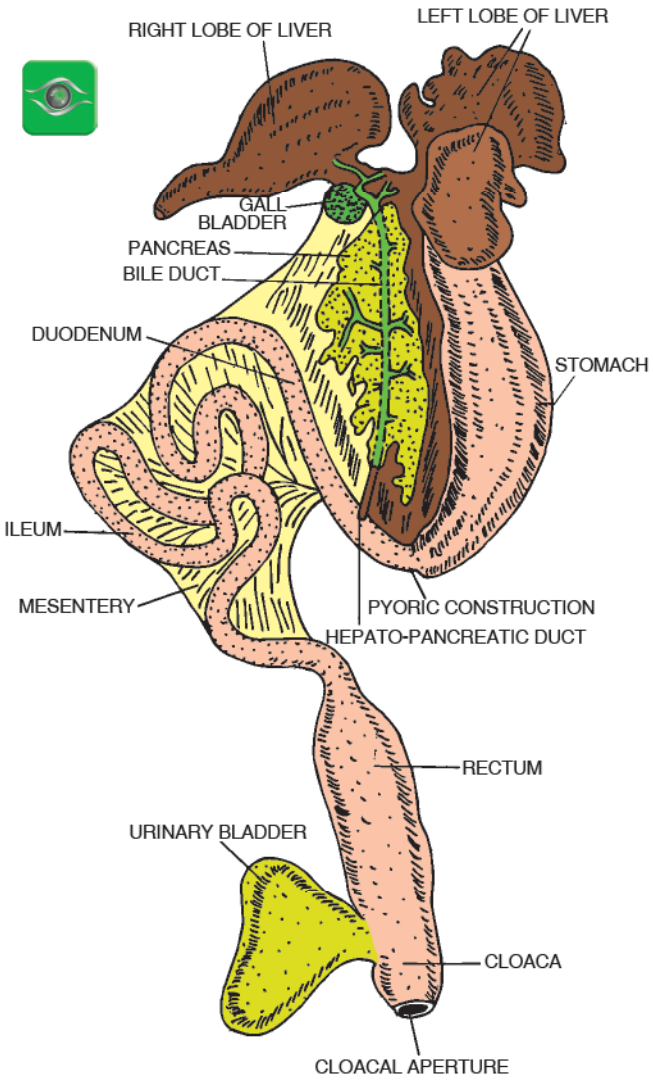


Fig. 95. Alimentary canal of frog.

(a) Teeth are present only on upper jaw and are of two types : numerous **maxillary teeth** (on maxilla bone of upper jaw) and two groups of **vomerine teeth** (on vomer bones). Teeth are **homodont** (similar), **acrodont** and **polyphyodont** (in many sets). These prevent the escape of prey so are **prehensile** in function.

(b) Tongue is thick, fleshy and muscular structure present on the floor of buccopharyngeal cavity. It is anteriorally fixed and posteriorally free and is protrusible to capture the prey.

(c) One pair of openings of **Eustachian tubes** connecting pharynx with the cavity of middle ear.

(d) One pair of openings of **vocal sacs** in pharynx (in only male frog) and act as **resonators**.

It also has a pair of **internal nares** (in the roof), **gullet** (in the centre) and **glottis** (below the gullet). Gullet is wide to swallow the prey entire. It also has three **subrostral fossae** just behind the tip of upper jaw and three **prelingual elevations** just behind the tip of lower jaw which fit into subrostral fossae to close the mouth.

(iii) Oesophagus is short and wide tube due to absence of neck.

(iv) Stomach is thick, muscular and **J-shaped.** It differentiated into proximal, broader and larger **cardiac stomach** and distal narrow and smaller **pyloric stomach.**

(v) Small intestine is long, narrow and tubular. It is differentiated into proximal **duodenum** (runs forward parallel to stomach) and distal **ileum** (coiled part).

Duodenum receives **hepatopancreatic** or common bile and pancreatic duct. Mucosa of small intestine is raised into finger-like folds, called **villi** and **microvilli** to increase the surface area of digestion and absorption.

(vi) Large intestine (Rectum) is shorter and wider tube. It stores the faeces temporarily and absorbs water from them. It opens in cloaca by anus.

(vii) Cloacal aperture (Described in morphology).

Digestive glands

(i) Liver in frog is solid, reddish-brown coloured and bilobed. Left lobe is larger in size and again divided into two lobes. It secretes a non-enzymatic **bile juice** which is temporarily stored in **gall bladder** (a thin walled bluish-green coloured rounded sac below the right liver lobe).

(ii) Gastric glands are simple tubular glands in the mucosa of stomach. These secrete gastric juices containing HCl and proteolytic pepsin.

(iii) Pancreas is an irregular and elongated cream-coloured gland present in the loop between stomach and duodenum. It secretes pancreatic juices containing trypsin, amylase, lipase, etc.

(iv) Intestinal glands are simple tubular glands present in the mucosa of intestine.

Physiology. Frog is **carnivorous** and feeds upon insects, spiders and worms. Prey is captured with the help of protrusible tongue **(Fig. 96)** and is swallowed entire. Pepsin digests the proteins in stomach in an acidic

medium provided by HCl. Bile has no digestive enzyme but helps in digestion by providing an alkaline medium and also emulsifies the fats. Pancreatic and intestinal juices complete the digestion of proteins, carbohydrates and fats in intestine.

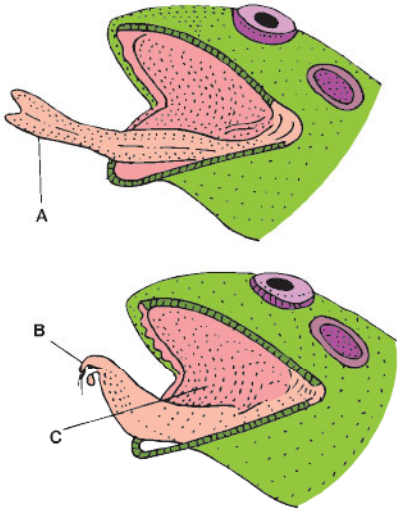


Fig. 96. Frog : Mode of ingestion.

4. Respiratory organs

Frog has **three types** of respiratory organs and mode of respiration :

(i) Cutaneous respiration. It is **most important** mode of respiration in which **skin** acts as **respiratory organ** so is thin, moist (with water and mucus), smooth, naked and vascular. It is an **amphibious organ of respiration** as helps in respiration both on land and in water. It is only mode of respiration in water, during hibernation and aestivation.

(ii) Buccopharyngeal or **mouth respiration.** In this, buccopharyngeal cavity acts as respiratory organ. For this it is lined by thin and moist mucous membrane which is also highly vascular.

(iii) Pulmonary or **lung respiration.** In this, respiratory organs are **lungs** which are connected to outside through a **respiratory tract** formed of **nostrils, nasal chambers, internal nares, glottis** and **laryngo-tracheal chamber.**

Lungs **(Fig. 97)** are a pair of elongated, hollow, thin-walled, pink-coloured and pear-shaped sac present in upper part of trunk. Their inner lining is raised into a number of septa to form a number of pockets, called **alveoli,** which act as sites of exchange of gases.

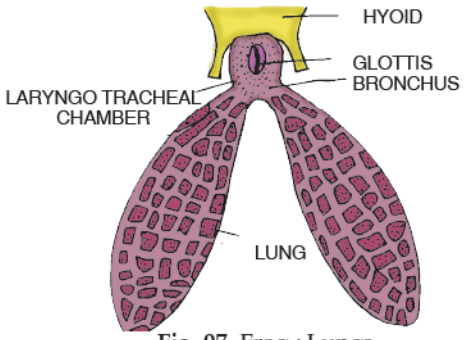


Fig. 97. Frog : Lungs.

Buccopharyngeal respiration and pulmonary respiration involve the movements of throat, called **respiratory movements,** with the help of two types of **respiratory muscles (Fig. 98) :**

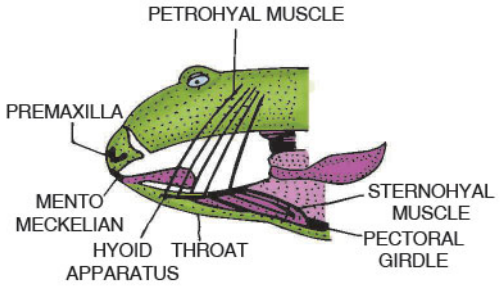


Fig. 98. Frog : Respiratory muscles.

(i) Sternohyal muscles extending from sternum to hyoid apparatus and when contract, these move the throat downward.

(ii) Petrohyal muscles extending from pro-otic bone of auditory capsule to hyoid apparatus and raise the throat on their contraction.

5. Circulatory system

Blood circulatory system of frog is of **closed type** and is formed of :

(i) Heart (Fig. 99). It is thick, muscular, conical, dark-red coloured and **three-chambered.** It lies in the upper part of body cavity between the lungs and is surrounded by a thin, transparent and 2-layered sac called **pericardium** having a watery **pericardial fluid** to protect the heart from mechanical shocks and mechanical injuries.

Three main chambers are : **Two auricles and one ventricle.** Auricles are thin-walled chambers and are separated by an **interauricular septum** while ventricle is unpartitioned. Right auricle is larger in size than left auricle. It also has two accessory chambers : **Sinus venosus** (a thin-walled triangular chamber on the dorsal side) and **truncus arteriosus** (an oblique tubular chamber on ventral side and in front of heart, it divides into 2 aortic trunks, each of which divides into three arches).

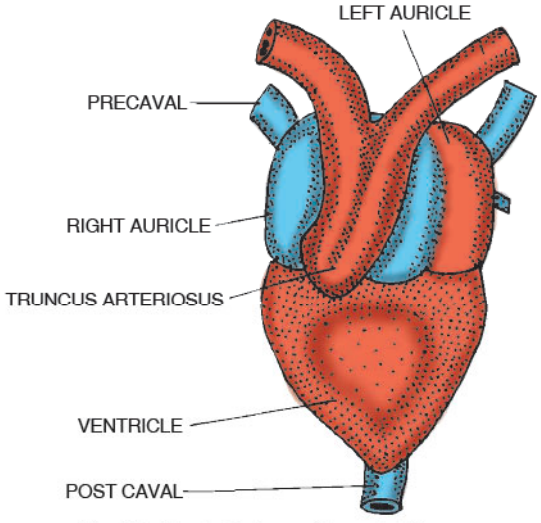


Fig. 99. Ventral view of heart of frog.

Sinus venosus receives the deoxygenated blood from the body parts by two anterior venae cavae (precavals) and one posterior vena cava (post caval). It gives deoxygenated blood to right auricle through sinu-auricular aperture. Left auricle receives oxygenated blood from lungs by pulmonary vein. Both auricles push the blood into ventricle which has **mixed blood** which is pumped to the body parts through truncus arteriosus and arches.

(ii) Blood vessels. These include arteries, veins and capillaries. In frog there are **3 pairs of aortic arches** which supply blood to various body parts.

(a) Carotids supply head region by internal and external carotids.

(b) Systemics supply most of body parts. Systemics give rise to arteries like : **Subclavian** (to fore limbs); **Coeliaco-mesenteric** (supplies liver and stomach by coeliac artery; and duodenum, pancreas, spleen and samll intestine by anterior mesenteric artery); **genitals** (to gonads); 4 or 5 pairs of **renals** (to the kidneys); **lumbar** arteries (to dorsal body wall); **posterior mesenteric** (to rectum); and **Iliac arteries** (to urinary bladder, ventral abdominal muscles and hind limbs).

(c) Pulmocutaneus supply skin and lungs.

Blood is collected by the veins and returned to sinus venosus by three venae cavae : **Precavals** collect the blood from the head by **external jagulars** (from tongue and lower jaw), **innominate veins** (from brain and shoulder) and **subclavian vein** (from fore limbs) while **post caval** collects the blood from posterior parts of body. Post caval of frog is formed of following veins: 4 or 5 pairs of **renals** (from the kidneys); **genital veins** (from the gonads) and **hepatic veins** (from liver). In frog, there are also two well-developed **portal systems :**

(a) Renal portal system is the venous connection between kidneys and lower body parts like hind limbs to remove nitrogenous wastes.

(b) Hepatic portal system is venous connection between liver and intestine.

So renal and hepatic portal systems are the examples of **functional adaptation.**

(iii) Blood. It is formed of liquid **plasma** and blood-cells, called **corpuscles.** The later are of three types :

(a) Erythrocytes (RBCs) are oval-shaped, biconvex and **nucleated.** These contain haemoglobin.

(b) Leucocytes (WBCs) are amoeboid or circular, whitish and nucleated. These are of five types : Neutrophils, basophils, eosinophils, lymphocytes and monocytes.

(c) Thrombocytes are spindle-shaped and nucleated. These help in **blood clotting.**

Lymphatic system of frog is formed of **lymph, lymph channels** and **lymph nodes.** Lymph differs from blood in having less proteins, calcium, phosphate and absence of erythrocytes. It is formed of plasma and leucocytes, so is called **filtered blood.** In frog, two large lymphatic sinuses are present : large **sub-cutaneous lymph sinus** (below the skin on dorsal and lateral sides) and **sub-vertebral lymph sinus** (below the vertebral column). Frog also has two pairs of **lymph hearts**.

6. Nervous system

(i) Central Nervous System (CNS) of frog is formed of brain and spinal cord. **Brain** is soft, whitish and slightly flattened structure present in the **cranial cavity** of cranium (brain box) of skull and is surrounded by two meningeal membranes (**Dura mater** and **pia-arachnoid).** Brain is divided into **three parts** :

(a) Fore brain is formed of a pair of **olfactory lobes** (for smell), a pair of **cerebral hemispheres** (collectively called **cerebrum** and control voluntary functions, intelligence, will, etc.) and an unpaired **diencephalon** (Its roof is called **epithalamus** and forms anterior choroid plexus and pineal body. Its floor is called **hypothalamus** and forms a part of pituitary gland. It acts as **relay centre**) **(Fig. 100).**

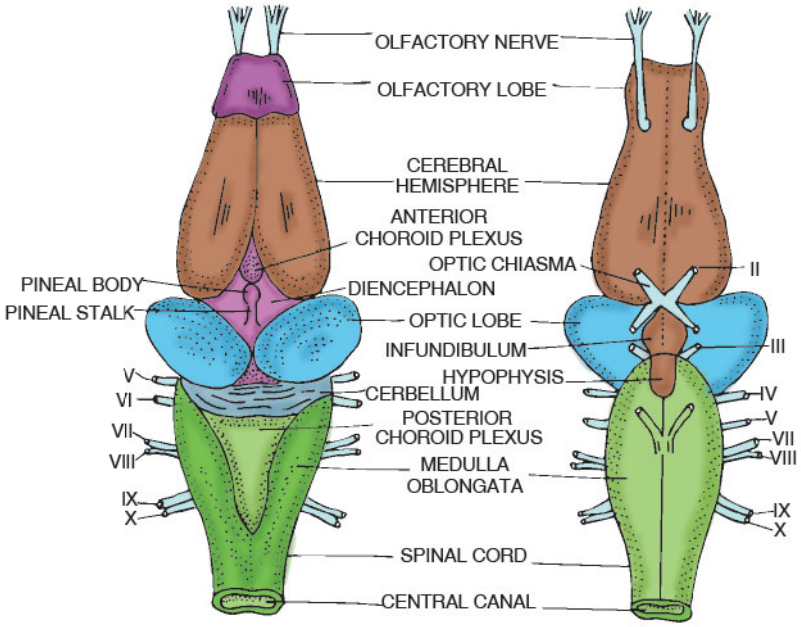


Fig. 100. Frog : Brain– **A.** Dorsal view; **B.** Ventral view.

(b) Mid brain is formed of **two optic lobes** (on dorsal side and control vision) and **two crura cerebri** (on ventral side and act as **coordination centres** between fore and hind brain).

(c) Hind brain is formed of two parts : **Cerebellum** (a transverse band on dorsal side and controls

equilibrium) and **medulla oblongata** (controls involuntary functions). Medulla oblongata continues into spinal cord through a wide aperture at the posterior end of skull, called **foramen magnum.**

Spinal cord of frog is elongated and slightly flattened structure present in the **neural canal** of vertebral column. It is with two longitudinal grooves, called **sulci or fissures,** and two swellings *i.e.* **Brachial** and **sciatic swellings**. Spinal cord forms a non-nervous thread-like **filum terminale** in the urostyle.

(ii) Peripheral Nervous System (PNS) of frog is formed of 10 pairs of **cranial nerves** (arising from brain and supplying head region) and 10 pairs of **spinal nerves.**

(iii) Autonomic Nervous System (ANS) is formed of sympathetic and para-sympathetic nervous systems which control the involuntary visceral functions.

7. Sense organs

(i) Eyes. In frog, there are one pair of large-sized, spherical **simple eyes**, bulging outward and located on dorsolateral sides of head. These lie in **orbits** or **eye sockets** of skull. Each eye is with three eye lids (Already explained) and is with a **harderian gland** whose secretion lubricates the eye ball and nictitating membrane. These are adapted for **monocular vision.** Wall of eye is formed of sclerotic, cornea, choroid, ciliary body, iris and retina. Retina is with photoreceptors.

Lens is large, spherical and is suspended in the cavity of eyeball just behind the iris from the ciliary body by a **suspensory ligament.** Cavity of eyeball is divided into anterior, smaller **aqueous chamber** and posterior, larger **vitreous chamber.**

(ii) Ears. Each ear of frog is formed of two parts :

(a) Middle ear is with an air-filled **tympanic cavity** externally covered by **ear drum** or **tympanum.** It is with single ear-ossicle, called **stapes** or **collumella auris**. Tympanic cavity is connected to pharynx through a narrow **Eustachian tube.**

(b) Internal ear is formed of 3 parts–upper **utriculus**, lower **sacculus** and three **semi-circular canals.** It has six sensory spots : **3 cristae** in ampullae and **3 maculae** out of which macula lagena is for hearing while other five spots are for equilibrium. So ear is an organ of **hearing and equilibrium.** There is **no external ear.**

Other sense organs of frog are **Taste buds** on tongue (for gustation or tasting the food), **nasal epithelium** (for olfaction or smell) and **tactile sensory papillae** (for touch in the skin).

8. Excretory system (Fig. 101)

Excretory system of frog is formed of :

(i) Kidneys are one pair of dark red, flattened and bean-like present in the posterior part of body cavity one on either side of vertebral column. These are **mesonephros** and symmetrical. Internally, each kidney is formed of 2,000 tubules called **uriniferous tubules** or **nephrons.** Each nephron is differentiated into two parts: a double-walled cup called **glomerulus** (it is site of ultrafiltration of water and wastes) and long and coiled **urinary tubule** (it is site of reabsorption of useful materials). Regarding excretion, frog is **ureotelic.**

(ii) Ureters. These arise from outer side of posterior end of kidneys, run backward and open in the roof of cloaca. Upper end of ureter in male frog swells to form **seminal vesicle** to store the sperms. Ureters of male frog act as **urinogenital canals** as carry both urine and sperms, while ureters of female frog carry only urine.

(iii) Urinary bladder. It is a bilobed and thin-walled sac present in the posterior part of body cavity ventral to rectum. It temporarily stores the urine.

(iv) Cloaca. It is small and thin-walled common sac in which rectum, ureters and reproductive ducts open. It opens out by **cloacal aperture.**

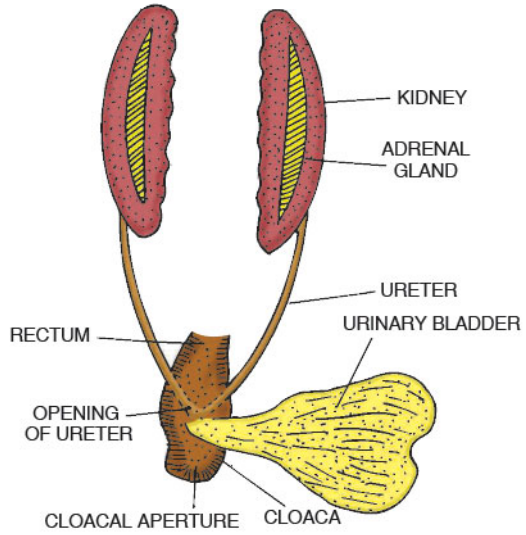


Fig. 101. Frog : Excretory system.

9. Reproductive system

(i) Male reproductive system (Fig. 101). It is formed of following parts :

(a) Testes. These are one pair of yellow-coloured, oval-shaped structures present on ventral side of outer margin of anterior part of kidneys. Each is suspended by a mesentary called **mesorchium.** Internally, each testis is formed of large number of **seminiferous tubules.** Each forms the sperms by **spermatogenesis.**

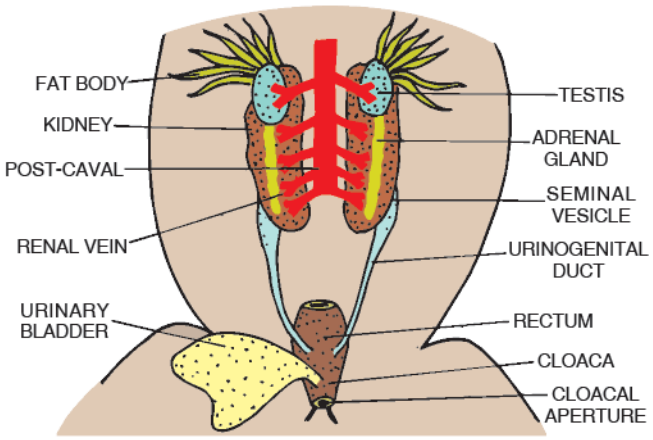


Fig. 102. Male urinogenital system.

(b) Vasa efferentia. These are 10-12 fine and ciliated tubules which collect the sperms from the seminiferous tubules, run inward and open in a longitudinal duct, called **Bidder's canal (Fig. 103)** present inside the kidney along its inner border.

(c) Ureters. These are one pair of longitudinal ducts which are connected to Bidder's canal by a number of transverse canals which receive urine from the uriniferous tubules. So ureters in male frog act as **urinogenital canals**. Each finally opens in cloaca.

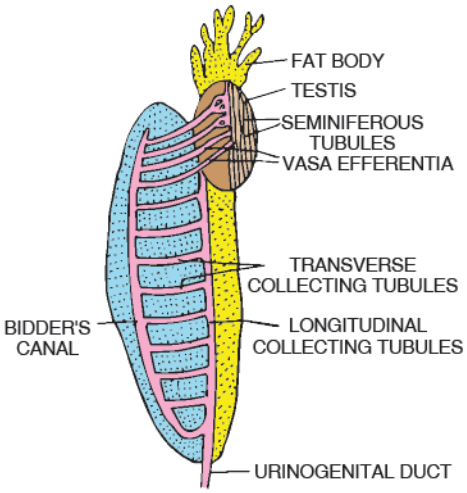


Fig. 103. Frog : Bidder's canal.

(ii) Female reproductive system (Fig. 104). It is formed of following parts :

(a) Ovaries. These are one pair of irregular and lobulated structures present on ventral side of outer border of the kidneys. Each ovary is suspended by a mesentry, called **mesovarium.** These produce ova by the process of **oogenesis.** Ova are released in body cavity by rupturing of ovaries.

(b) Genital ducts. These are one pair of long and convoluted structures. Each is differentiated into three parts: **Fallopian funnel** receives the ova through an inward directed wide aperture, called **ostium; Oviduct** (middle and convoluted part and secrete three jelly coats around the ova) and **Ovisac or uterus** (lower and dilated part which stores the ova) which finally opens in the roof of cloaca.

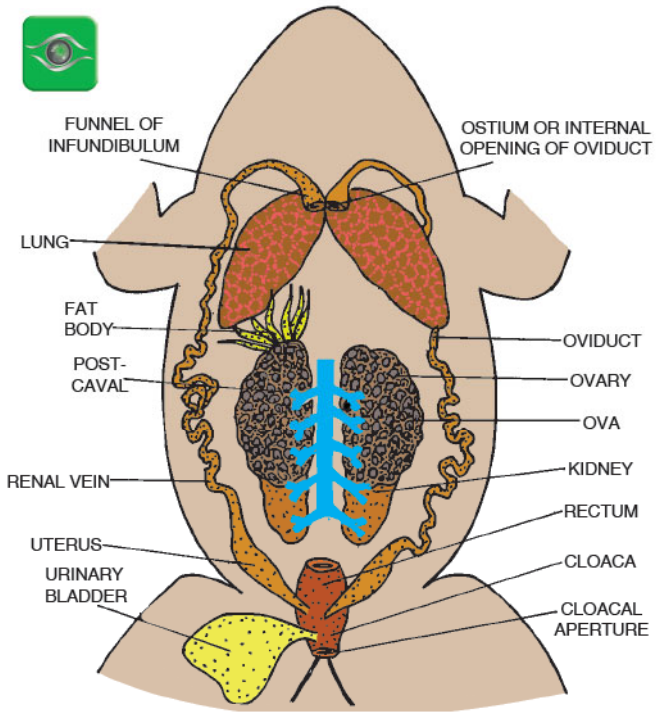


Fig. 104. Female urinogenital system.

10. Development

Bull frog of India breeds in shallow waters from July to September (during rainy season). Males are first to reach the shallow waters and croak to attract the females and two sexes show a sexual embrace, called **amplexus (Fig. 105)**, for a few days. Nuptial pads of male frog help in amplexus. Female releases 2500-3000 ova in a gelatinous mass, called **spawn,** and the process is called **spawning.**

Fertilization is **external** and development is **indirect** as includes a fish-like aquatic, herbivorous and gill-breathing **tadpole larva** which undergoes **progressive metamorphosis** to become adult.

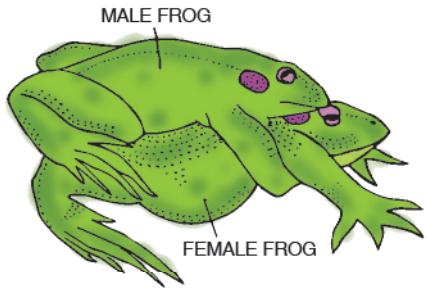


Fig. 105. Frog : Amplexus.

Interaction with Mankind (Economic Importance)

Frog is a **useful animal** due to following reasons :

(i) It is used in **biological control** as eats upon crop's pest insects e.g. bugs or insects carrying the pathogenic organisms like West Nile virus.

(ii) It is used as an **experimental animal** for teaching, research, pharmacology, etc.

(iii) Its muscular legs are **used as food** in some parts of India and many other countries.

(iv) Small froglets are used **as fish-bait.**

(v) These form a **food link** in the ecosystem.

(vi) These are important part of biology education. African clawed frog is modern day "**lab rat**."

(vii) Frogs also have **cultural importance** and are symbol of fertility in ancient Egypt; as rain god for Native Americans; symbol of good luck in Japan; etc.

Due to overuse of pesticides; their large scale use for dissection purposes and habitat destruction, frog has become a **threatened species** and their rapid decline in number is causing huge loss to bio-diversity and creating environmental problems.

SUPPLEMENT YOUR KNOWLEDGE

- Frogs never drink water but absorb it through their skin and store in their subcutaneous lymph sinuses.
- **Squatting :** That sitting posture in which three parts of hind limbs are folded in the form of Z-position to support the posterior part of the body and act as springs.
- **Pulmonary respiration** is least important type of respiration in frog as is less frequent.
- **Laryngo-tracheal chamber** of frog acts as sound-producing organ.
- Passing of air from outside into buccopharyngeal cavity is called **aspiration** in pulmonary respiration.
- Heart of frog is **myogenic** and **autoexcitable** and is controlled by **sinu-auricular node** of cardiac muscles which acts as **pace maker** of heart.
- On dry days, frog becomes **uricotelic.**
- Cavities of different lobes of brain are called **ventricles** and are filled with a watery fluid called **cerebrospinal fluid.**
- Eye balls of frog can be protruded out or withdrawn inside the orbits by the contraction of **protractor bulbi** and **retractor bulbi** muscles.
- Internal ear is also called **membranous labyrinth.**
- In frog, excretory (urinary) system and reproductive system are joined to form **urinogenital system**.
- Copulatory organs are absent in frog.
- Route of sperms in male frog is: Testes –> Vasa efferentia –> Kidneys –> Bidder's canals –> Urino-genital canals –> Cloaca.
- Ovaries of female frog are large sized and dark coloured during breeding season.
- In frog, buccopharyngeal cavity and lungs act as **aerial respiratory organs.**
- Ovaries of frog have no functional connection with the kidneys.
- Frog has both nervous system and endocrine system for control and coordination of body functions.
- Endocrine glands of frog are : pituitary, thyroid, parathyroid, thymus, pineal, pancreas, adrenals and gonads. These secrete **hormones** which help in **chemical coordination** of body functions.

PRACTICE PROBLEMS – FROG

128. What is nature of skin in frog?
129. Why are the eyes of frog located on the dorsolateral sides of head and bulging outward?
130. What is nictitating membrane? Give its function.
131. What are vocal sacs? Give their function.
132. Define amplexusory pads. What is their function?
133. Name the skin folds between the toes. What is their function?
134. Why are three parts of legs of frog folded in Z-form?
135. List two differences between male and female frog.
136. What is nature of tongue of frog?
137. What is pericardium?
138. Name the main as well as accessory chambers of heart of frog.
139. Give one difference between the RBCs of frog and those of rat.
140. How many cranial nerves are present in frog and rabbit?
141. What are the two functions of ear?
142. Name the excretory units of kidneys of frog and rabbit.
143. What is Bidder's canal?
144. Name the mesentery which suspends testis in frog.
145. What is spawn?

ANSWERS TO PRACTICE PROBLEMS

128. Skin of frog is thin, moist, glandular and **respiratory.** It has **no exoskeleton.**

129. To increase the area of vision by the eyes due to absence of neck.

130. It is a thin, transparent and freely **movable skin fold** which is moved to clean the cornea.

131. These are balloon-like distensible structures present on floor of male frog. These act as **resonators** and increase the pitch of sound.

132. These are glandular pads present on ventral side of index fingers of male frog. These are enlarged in breeding season. Their secretion helps in griping female frog during amplexus.

133. Webs. These help in swimming of frog.

134. For leaping.

135. Male frog has vocal sacs and amplexusory pads while these are absent in female frog.

136. It is anteriorally fixed, posteriorally free and bilobed and is protrusible.

137. A 2-layer sac which surrounds the heart.

138. Three main chambers are : 2-auricles and 1 ventricle, while two accessory chambers are : sinus venosus and conus arteriosus.

139. RBCs of frog are biconvex and nucleated, while these are biconcave and denucleated in rat.

140. Ten pairs in frog and twelve pairs in rat.

141. Hearing and equilibrium.

142. Nephrons.

143. A longitudinal canal inside the kidney of frog and receives sperms from testis by vasa efferentia.

144. Mesorchium.

145. A mass of 2500–3000 ova laid by female frog.

CHAPTER SUMMARY

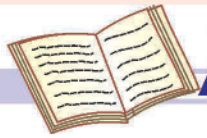
- **Cell** is the structural and functional unit of all the organisms. A **tissue** is the group of cells which coordinate to perform some specific function. Tissue may be **simple** or **compound**. Tissue help in division of labour and integration and cooperative biological processes. Study of tissues is called **histology**.
- **Tissues** are of **four types: Epithelial** (for covering and protection), **muscular tissue** (contractile for movements and locomotion), **connective tissue** (for binding, transportation and supporting) and **nervous tissue** (conduction of nerve impulses).
- In **Epithelial tissues**, the cells are arranged in layers, compactly arranged, resting on a basement membrane, with a number of junctional complexes but no intercellular spaces. These are of two types : **Covering** and **glandular** tissues. Covering tissues are either **unilaminar** or **multilaminar**. Unilaminar epithelia may be squamous, cuboidal or columnar epithelia. Cuboidal epithelium is pigmented (retina of eye) or ciliated (nephrons of kidneys) or brush-bordered (PCT of nephrons). Columnar epithelium is ciliated (Fallopian tubes) or brush–bordered (intestinal mucosa) or pseudostratified (Trachea). Multilaminar epithelium is either stratified (epidermis of vertebrate's skin) or transitional (urinary bladder and ureters). **Glandular epithelia** have either unicellular or multicelluar glands. The later are either tubular or saccular. Glands are exocrine (e.g. salivary glands) or endocrine (e.g. thyroid) or heterocrine (e.g. pancreas).
- **Muscular tissues** are generally mesodermal in origin and are formed of long, fibre-like and contractile muscle fibres. These form muscles which help in movements of body parts and locomotion. Muscular tissues are of three types: **skeletal, visceral** and **cardiac muscle fibres.** Skeletal muscle fibres are striated (with A and I bands), syncitial and voluntary in nature. Visceral muscle fibres are unstriated, smooth and involuntary in nature while cardiac muscle fibres of heart are stratified, but uninucleated and involuntary and undergo rhythmic contractions.
- **Connective tissue** is also mesodermal in origin and is characterized by large intercellular spaces filled with matrix. Connective tissue is of three types: **connective tissue proper** (soft matrix), **skeletal connective tissue** (mineralised matrix) and **vascular tissue** (with fluidy matrix). Connective tissue proper is either **areolar** (or loose fibrous) or **adipose C.T.** (with fat-filled adipocytes) or **tendon** (with bundles of white fibres) or **ligament** (with numerous yellow fibres) or **reticular C.T.** with star-shaped reticular cells). **Skeletal C.T.** is formed of **cartilages** and **bones.** Cartilage has a glycoproteinous matrix with chondrin secreted by oval- shaped chondroblasts. Cartilages may be hyaline or fibrous or calcified. Bone is characterized by marrow cavity with bone marrow, haversian systems and periosteum. **Vascular C.T.** includes blood and lymph which flow in vessels and transport the materials inside the body. **Blood** is formed of plasma and blood corpuscles. Blood corpuscles are of three types: **RCBs** (Biconcave and denucleated in mammals and with haemoglobin meant for O_2 transportation), **WBCs** and **blood platelets** (cytoplasmic fragments which help in blood clotting at injury). WBCs are of five types: Neutrophils (soldiers), eosinophils, basophils, monocytes (scavengers) and lymphocytes (immune cells). Lymph is formed of plasma and only leucocytes.

- **Nervous tissue** has the properties of excitability and conductivity. It is a compound tissue and is formed of four types of cells: **neurons, neuroglia** (supporting cells between neurons), **neurosecretory cells** (secrete neuro - hormones) and **ependymal cells.** A neuron is formed of cyton and two types of nerve processes: axon and dendrons. Nerve processes form two types of nerve fibres: **Medullated** and **non-medullated.**
- **Earthworm** *(Pheretina posthuma)* is terrestrial and fossorial annelid. It is nocturnal, shows cutaneous respiration, creeping locomotion with the help of setae, detritivorous in feeding, bisexual but shows cross- fertilization due to protandrous condition and direct development. Morphologically, it is characterized by **metameric segmentation,** glandular band **clitellum,** female and male gonopores, spermathecal pores, genital papillae and perichaetine arrangement of setae. Alimentary canal is characterized by long, tubular and sacculated intestine having **typhlosole** in its middle region. Excretion occurs by **nephridia** and chloragogen cells. Nephridia are integumentary (attached on skin), pharyngeal and septal nephridia (attached on septa). Earthworm has **closed circulatory system** characterized by longitudinally arranged blood vessels., 4 pairs of hearts, 2 pairs of anterior loops and red-coloured blood (due to red pigment erythrocruorin). **CNS** of earthworm is of a circumpharyngeal nerve ring and single, ventral, solid and ganglionated nerve cord. Male reproductive system has 2 pairs of testes enclosed in testis sacs, 2 pair of seminal vesicles and l pair of prostate glands. Female reproductive system has one pair of palmate ovaries, oviducal funnels, oviducts, 4 pairs of spermathecae and 2 pairs of accessory glands. Earthworm is an animal of **mixed blessing.** It is employed in **vermicomposting.**
- **Cockroach** (*Periplaneta americana*) is terrestrial, nocturnal, cursorial but rarely flies, omnivorous and unisexual arthropod. Its body is covered by a **sclerotized exoskeleton** of chitinous plates called **sclerites**. Body is divided into head, thorax and abdomen. **Head** is **hypognathous** and is covered by a head capsule of six sclerites, has 3 types of head appendages: antennae, eyes and fenestrae; and biting and chewing type mouth parts : Labrum, mandibles, first maxillae, labium and hypopharynx. **Thorax** is 3 segmented and has 3 pairs of legs and 2 pairs of wings. Each leg is formed of 5 podomeres. Forewings act as wing covers or tegmina, while hind wings help in flying. **Abdomen** is 10-segmented in adult and bears anal cerci, anal styles (only in male cockroach) and gonapophyses (3 in male while 3 pairs in female cockroach). Cockroach shows **sexual dimorphism** and differs in abdomen, sterna, terga, brood pouch and anal styles. **Alimentary canal** is characterized by food storing crop., food-masticating gizzard, long and coiled mesenteron, hepatic caecae etc. Respiration occurs by a network of ectodermal tubes, called **tracheae,** which open out by spiracles. **Circulatory system** is of open-type and includes 13 chambered heart, 3 chambered haemocoel. 13 pairs of alary muscles and colourless blood called haemolymph. **Excretory structures** of cockroach are yellow coloured, thread-like malpighian tubules, urate cells of fat body, nephrocytes and uricose glands. Cockroach is uricotelic in excretion. **CNS** is formed of a circum-oesophageal nerve ring and double, ventral, solid and 9-ganglionated nerve cord. **Sense organs** of cockroach are compound eyes, antennae and sensillae. Compound eye is formed of ommatidia and adapted for apposition vision. **Male reproductive system** is formed of trilobulated testes, utricular gland, phallic gland, ejaculatory duct and 3 gonapophyses. A sperm sac, called **spermatophore,** is formed. **Female reproductive system** is formed of a pair of ovaries, brood pouch, collateral glands, spermathecae and 3 pairs of gonapophyses. Fertilization is internal. 16 eggs are arranged in 2 rows in ootheca. **Development** includes **gradual metamorphosis.** Cockroach is an animal of mixed blessing.
- **Frog** *(Rana tigrina)* is an amphibious, diurnal, carnivorous and unisexual amphibian. It shows swimming and leaping locomotion, hibernation in winter months, and protective colouration. Body is formed of 2 parts : head and trunk. **Head** bears wide mouth, nostrils, bulging eye balls, brow spot, tympanum and vocal sacs (in male). **Trunk** bears 2 pairs of limbs. Webs are present between toes. **Alimentary canal** has homodont teeth in buccal cavity, small oesophagus, J- shaped stomach, convoluted small intestine and wide rectum which opens in cloaca. **Respiratory organs** are skin (cutaneus respiration) as well as lungs (Pulmonary respiration). **Heart** of frog is formed of 2 auricles and single ventricle, both accessory chambers– truncus arteriosus and sinus venosus are present. Frog has 3 pairs of arches and both renal and hepatic portal systems. RBCs are oval and nucleated. **CNS** is formed of brain and spinal cord. Brain lies in cranial cavity of skull and is covered by 2 meningeal membrane. **PNS** of frog is formed of 10 pairs of cranial nerves and 10 pairs of spinal nerves. **Eyes** of frog lie in orbits on dorsolateral sides of head while each **ear** is formed of only middle and internal ear. **Excretory system** is formed of kidneys, ureters and urinary bladder. Frog is ureotelic in excretion. **Male reproductive system** is formed of a pair of testes, vasa efferentia, Bidder's canal and ureters, while **female reproductive system** is formed of ovaries, convoluted oviducts and cloaca. Copulation involves **amplexus** and spawning. Fertilization is external and development includes **tadpole larva**. Frog is useful as food, fish-bait and biological control agent.

KEY TERMS

Adipose tissue	:	Fat storing connective tissue.
Amplexusory pad	:	Copulatory pad present on ventral side of index finger in male frog.
Anal cerci	:	Jointed tactile and auditory structures of cockroach .
Anal styles	:	Needle- like copulatory structures in male cockroach only.
Annuli	:	Ringlike grooves on the body of earthworm.

Axon	:	An elongated nerve process of neuron.
Chondrin	:	A protein which forms the cartilage.
Chondroblast	:	Cartilage cell.
Clitellum	:	Glandular band surrounding 14th, 15th & 16th segments of earthworm.
Cyton	:	Nucleated part of a nerve cell.
Dendron	:	Small sized nerve process of a nerve cell.
Erythropoeisis	:	Formation of red blood corpuscles.
Fibroblasts	:	Connective tissue cells which form fibres.
Goblet cells	:	Mucilage forming cells.
Haemocytometer	:	Instrument used to determine RBC-count.
Haemolysis	:	Breaking of red blood cells.
Haemometer	:	Instrument used to know percentage of haemoglobin in blood.
Haversian canals	:	Narrow longitudinal canals in the bone.
Histology	:	Study of tissues.
Hypognathous	:	Downward directed head of cockroach.
Leukaemia	:	An increase in the number of WBCs in blood.
Ligament	:	A band of yellow fibres which joins bones together.
Metameres	:	Segments of body of earthworm.
Neuroglia	:	Non-nervous packing cells of nervous tissue.
Ommatidia	:	Visual units of compound eye of cockroach.
Osteocyte	:	Bone cell.
Sclerites	:	Chitinous plates which form exoskeleton of cockroach.
Sternum	:	Ventral sclerite of cockroach.
Synapse	:	A juxtaposition between two neurons or between one neuron and a muscle fibre.
Tendon	:	A band of white fibres which joins muscles to the bone.
Tergum	:	Dorsal sclerite of cockroach.
Thrombocytopenia	:	Decrease in number of blood platelets.
Thrombocytosis	:	Increase in number of blood platelets.
Tissue	:	A group of cells coordinating to perform a specific function.
Vocal sacs	:	Skin pouches on throat of male frog to increase the pitch of sound.
Volkmann's canals	:	Small, transverse canals which interconnect Haversian canals.



NCERT FILE Solved

NCERT Exercise Questions

1. Answer in one word or one line :

Question	Answer
(i) Give the common name of *Periplaneta americana*.	American cockroach.
(ii) How many spermathecae are found in earthworm?	Four pairs.
(iii) What is position of ovaries in cockroach?	In 2nd to 6th abdominal segments.
(iv) How many segments are present in the abdomen of cockroach?	Ten segments.
(v) Where do you find Malpighian tubules?	At the junction of midgut and ileum of hind- gut.

2. Answer the following:

(i) What is the function of nephridia?

Ans. Nephridia are excretory organs of earthworm.

(ii) How many types of nephridia are found in earthworm based on their location?

Ans. Three types of nephridia — septal, pharyngeal and integumentary nephridia.

3. Draw a labelled diagram of the reproductive organs of an earthworm.

Ans. See Fig. 64 of the chapter 7.

4. Draw a labelled diagram of alimentary canal of a cockroach.

Ans. See Fig. 76 of the chapter 7.

5. Distinguish between the followings:

(a) Prostomium and peristomium.

Ans. **Peristomium** is first segment of earthworm and surrounds the mouth, while **prostomium** is a fleshy extension of peristomium and lies dorsal to mouth.

(b) Septal nephridium and pharyngeal nephridium.

Ans. **Septal nephridium** is attached on intersegmental septum from 15th segment onward and is with ciliated funnel so called **open type**, while **pharyngeal nephridium** is present in one of 4th and 6th segments and lacks ciliated funnel so called **closed type**.

6. What are cellular components of blood?

Ans. Cellular components of blood are Erythrocytes (RBCs), leucocytes (WBCs) and platelets (in human blood) or thrombocytes (in frog's blood).

7. What are the following and where do you find them in animal body?

(i) Chondrocytes **(ii)** Axon and **(iii)** Ciliated epithelium

Structure	Description
(a) Chondrocytes :	These are oval-shaped cartilage cells present in groups of 2 or 4 in the matrix of cartilages of pinna, tracheal and bronchial rings, nasal septum etc.
(b) Axons :	These are long and cylindrical processes of the neurons of nervous tissue. These are efferent in nature and conduct nerve impulses away from the cyton. Their terminal ends may be branched to form terminal arborizations.
(c) Ciliated epithelium :	It is formed of cuboidal or columnar cells having fine hair -like cilia on their free border. Ciliated cuboidal epithelium lines some parts of nephrons of the kidneys, while ciliated columnar epithelium is found in the fallopian tubes.

8. Describe various types of epithelial tissues with the help of labelled diagrams.

Ans. See epithelial tissues of the text of chapter 7.

9. Distinguish between :

(i) Simple epithelium and compound epithelium.

Ans. Simple epithelium is unilaminar while compound epithelium is multilaminar.

(ii) Cardiac muscle and striated muscle.

Ans. See table 11 of chapter 7.

(iii) Dense regular and dense irregular connective tissues.

Ans. **Dense regular connective tissue** is formed of bundles of white fibres running parallel to one another so form tough and inelastic structures e.g. **tendons** which join muscles with the bones.

Dense irregular connective tissue is formed of bundles of white fibres arranged in a criss-cross manner and has areolar. It forms **sheaths** like pericardium, dura-mater, periosteum, perichondrium and capsules around testes, kidneys, etc.

(iv) Adipose and blood tissue.

Ans. **Adipose tissue** is a type of connective tissue proper having soft matrix with numerous rounded **adipocytes**, each of which has either a large fat globule or a number of small fat droplets. It is present beneath the skin and helps in homeothermy.

Blood is red vascular connective tissue having fluidy matrix, called **plasma**, not secreted by blood cells. Plasma has **3 types of corpuscles** — Erythrocytes (RBCs), leucocytes (WBCs) and platelets in man. Blood mainly helps in transportation of materials inside the body.

(v) Simple gland and compound gland.

Ans. **Simple glands** may be straight or coiled, unbranched or branched once. These may be tubular-shaped (e.g. crypts of Lieberkuhn of intestine, sweat glands of skin, gastric glands of stomach) or saccular- shaped (e.g. oil glands of skin).

Compound glands are branched a number of times. These may be compound tubular (e.g. milk glands of egg laying mammals) or compound saccular (e.g. milk glands of humans).

10. Mark the odd one in each series :

(i) Areolar tissue ; blood ; neuron ; tendon.

(ii) RBC; WBC; platelets; cartilage.

(iii) Exocrine; endocrine; salivary gland; ligament.

(iv) Maxilla; mandible; labrum; antenna.

(v) Prothorax; mesothorax; metathorax, coxa.

Ans. **(i)** Neuron; **(ii)** Cartilage; **(iii)** Ligament; **(iv)** Antenna; **(v)** Coxa.

11. Match the terms in Column I with those in Column II.

Column I	Column II
(a) Compound epithelium	(i) Alimentary canal
(b) Compound eye	(ii) Cockroach
(c) Septal nephridia	(iii) Skin
(d) Open circulatory system	(iv) Mosaic vision
(e) Typhlosole	(v) Earthworm
(f) Osteocyte	(vi) Phallomere
(g) Genitalia	(vii) Bone

Ans. **(a) (iii); (b) (iv); (c) (v); (d) (ii) ; (e) (i) ; (f) (vii); (g) (vi).**

12. Mention briefly about the circulatory system of earthworm.

Ans. See page no. 41-42 of chapter 7.

13. Draw a neat diagram of digestive system of frog.

Ans. See Fig. 95 of chapter 7.

14. Mention the function of the following structures :

Structure	Function
(a) Ureters in frog :	In male, these carry urine and sperms so also called **urinogenital canals**, while in female, these carry only urine.
(b) Malpighian tubules :	These help in excretion and osmoregulation in insects.
(c) Body wall in earthworm :	Protection to internal organs; gives definite shape; forms setae for locomotion and helps in respiration.

NCERT Exemplar Problems

A. MULTIPLE CHOICE QUESTIONS

1. Which one of the following types of cell is involved in making of the inner walls of large blood vessels?
(a) Cuboidal epithelium (b) Columnar epithelium
(c) Squamous epithelium (d) Stratified epithelium

2. To which one of the following categories does adipose tissue belong?
(a) Epithelial (b) Connective
(c) Muscular (d) Neural

3. Which one of the following is not a connective tissue?
(a) Bone (b) Cartilage
(c) Blood (d) Muscles

4. The clitellum is a distinct part in the body of earthworm, it is found in?
(a) Segments 13 - 14 - 15 (b) Segments 14 - 15 - 16
(c) Segments 12 - 13 - 14 (d) Segments 15 - 16 - 17

5. Setae help in locomotion in earthworm but not uniformly present in all the segments. Select among the following that represents setae:
(a) 1st segment (b) Last segment
(c) Clitellar segment (d) 20th - 22nd segment

6. Which one of the following statements is true for cockroach?
(a) The number of ovarioles in each ovary are ten
(b) The larval stage is called caterpillar
(c) Anal styles are absent in females
(d) They are ureotelic

7. Match the followings and choose the correct option:

(A) Adipose tissue	(i) Nose
(B) Stratified epithelium	(ii) Blood
(C) Hyaline cartilage	(iii) skin
(D) Fluid connective tissue	(iv) Fat storage

Options:
(a) (A) - (i) (B) - (ii) (C) - (iii) (D) - (iv)
(b) (A) - (iv) (B) - (iii) (C) - (i) (D) - (ii)
(c) (A) - (iii) (B) - (i) (C) - (iv) (D) - (ii)
(d) (A) - (ii) (B) - (i) (C) - (iv) (D) - (iii)

8. Match the followings and choose the correct answer:

(A) Hermaphrodite	(i) Produces blood cells and haemoglobin
(B) Direct development	(ii) Testis and ovary in the same animal
(C) Chemoreceptor	(iii) Larval form absent
(D) Blood gland in earthworm	(iv) Sense of chemical substances

Options:
(a) (A) - (ii) (B) - (iii) (C) - (iv) (D) - (i)
(b) (A) - (iii) (B) - (ii) (C) - (iv) (D) - (i)
(c) (A) - (i) (B) - (iii) (C) - (ii) (D) - (iv)
(d) (A) - (ii) (B) - (iv) (C) - (iii) (D) - (i)

9. Match the following with reference to Cockroach and choose the correct option:

(A) Phallomere	(i) Chain of developing ova
(B) Gonopore	(ii) Bundles of sperm
(C) Spermatophore	(iii) Opening of the ejaculatory duct
(D) Ovarioles	(iv) The external genitalia

Options:
(a) (A) - (iii) (B) - (iv) (C) - (ii) (D) - (i)
(b) (A) - (iv) (B) - (iii) (C) - (ii) (D) - (i)
(c) (A) - (iv) (B) - (ii) (C) - (iii) (D) - (i)
(d) (A) - (ii) (B) - (iv) (C) - (iii) (D) - (i)

10. Match the followings and choose the correct answer:

(A) Touch	(i) Nasal epithelium
(B) Smell	(ii) Foramen magnum
(C) Cranial nerves	(iii) Sensory papillae
(D) Medulla oblongata	(iv) Peripheral nervous system

Options:
(a) (A) - (iii) (B) - (i) (C) - (ii) (D) - (iv)
(b) (A) - (ii) (B) - (i) (C) - (iv) (D) - (iii)
(c) (A) - (iii) (B) - (iv) (C) - (ii) (D) - (i)
(d) (A) - (iii) (B) - (i) (C) - (iv) (D) - (ii)

ANSWERS

1. (c); **2.** (b); **3.** (c); **4.** (b); **5.** (d); **6.** (c); **7.** (b); **8.** (a); **9.** (b); **10.** (d);

HINTS FOR SOME DIFFICULT MULTIPLE CHOICE QUESTIONS

2. (b) : Adipose tissue is a type of soft connective tissue in which matrix has large number of spherical fat-filled adipocytes.

5. (d) : Setae are absent from Ist, clitellar and last (anal) segment of earthworm. All other segments have ring-arrangements of setae.

9. (b) : This is only choice of right combinations.

B. VERY SHORT ANSWER TYPE QUESTIONS

1. State the number of segments in earthworm which are covered by a prominent dark band called clitellum.

Ans. 14th, 15th and 16th segments (**clitellar segments**).

2. Where are sclerites present in cockroach?

Ans. Sclerites form the **exoskeleton** of body of cockroach. These are chitinous plates.

3. How many times, do nymphs moult to reach the adult form of cockroach?

Ans. In cockroach, nymph undergoes **13 moultings** to become adult.

4. Identify the sex of a frog in which sound producing vocal sacs are present.

Ans. Male frog. Vocal sacs increase the pitch of sound.

5. Name the process by which a tadpole develops into adult frog.

Ans. Metamorphosis.

6. What is the scientific term given to earthworm's body segments?

Ans. Metameres or somites.

7. A muscle fibre tapers at both ends and does not show striations. Name the muscle fibre.

Ans. Smooth or unstriated or involuntary muscle fibre.

8. Name the different cell junctions found in the tissues.

Ans. **(a)** Tight junctions; **(b)** Adhering junctions; **(c)** Gap junctions.

9. Give two identifying features of an adult male frog.

Ans. **(a)** Presence of **Vocal sacs.**

(b) Presence of copulatory or **amplexusory pads** on index fingers.

10. Which mouth part of cockroach is comparable to our tongue?

Ans. Hypopharynx.

11. The digestive system of frog is formed of following parts. Arrange them in an order beginning from mouth:

Mouth, oesophagus, buccal cavity, stomach, intestine, cloaca, rectum, cloacal aperture.

Ans. Mouth, Buccal cavity, oesophagus, stomach, intestine, rectum, cloaca, cloacal aperture.

12. What is difference between cutaneous and pulmonary respiration.

Ans. In **cutaneous respiration**, exchange of gases occurs through thin, moist and vascular skin; while in **pulmonary respiration** lungs are respiratory organs.

13. Special venous connection between liver and intestine and between kidney and lower parts of body is found in frog. What are they called?

Ans. Venous connection between liver and intestine is called **Hepatic portal system**, while venous connection between kidney and lower parts of body is called **Renel portal system.**

C. SHORT ANSWER TYPE QUESTIONS

1. Give the location of hepatic caecae in Cockroach. What is their function?

Ans. Hepatic caecae are 6 to 8 finger-like outgrowths located at anterior end of mesenteron. These secrete digestive enzymes.

2. Frogs are beneficial for mankind. Justify the statement.

Ans. (i) These eat upon insect-pests and help in their **biological control.**

(ii) These are used as **experimental animals** for pharmacological studies.

(iii) Used as **food** in some countries.

(iv) Act as important **food link** in the ecosystem.

3. The body of sponges does not possess tissue level organisation though it is made of thousands of cells. Comment.

Ans. Because cells of the sponges do not show coordination to perform specific function. These simply behave as cell-aggregates in which division of labour is also at cellular level.

4. Structural organisation in animals attains different levels as cell—organ—organ system. What is missing in this chain? Mention the significance of such an organisation.

Ans. In this chain of structural organisation in animals, **tissue organisation** is missing. A tissue is group of cells which alongwith intercellular material performs a specific function. There are four basic types of tissues which are organised in specific proportion and pattern to form specific organ to perform specific function. Formation of organs and organ-systems increases their efficiency and coordination.

5. Stratified epithelial cells have limited role in secretion. Justify their role in our skin.

Ans. Stratified epithelium is formed of many layers of cells and is found in those regions of body where there is more wear and tear e.g. **skin** so is mainly protective in function. Being many layered, it has limited role in secretion and absorption.

6. How does a gap junction facilitate intercellular communication?

Ans. Gap junctions are microscopic tunnels between the adjacent animal cells. These help in intercellular communication by rapid transfer of ions, small biomolecules and rarely large biomolecules between the cytoplasm of adjacent cells.

7. Why are blood, bone and cartilage called connective tissues?

Ans. Because in all these, there are **large intercellular spaces** between the cells which are filled with large amount of ground substance, called **matrix**, secreted by the cells of tissue. In matrix, protein fibres are generally present.

8. Why are neurons called excitable cells? Mention special features of the membrane of the neuron.

Ans. Neurons are called excitable cells because these can be excited (depolarised) by a stimulus of proper strength. Special features of membrane of neurons are:

(i) Neuronal membrane is electropositive on outside and electronegative on inner side. In a polarised neuron, a rest potential of – 90 mV is present.

(ii) Different types of ion-channels are present.

(iii) There is more Na^+ in extra neuronal fluid and more K^+ in the neuroplasm.

9. Why earthworm is called the "friend of farmer"?

Ans. Earthworm is called "**friend of the farmer**" because it improves the soil fertility in a number of ways like:

(i) Its burrowing habit improves **soil aeration** which improves respiration and easy penetration of roots in the soil.

(ii) It carries decaying vegetation in the burrow which it changes into **humus.**

(iii) It brings **mineral-rich subsoil** on the surface.

(iv) Its faecal matter has **manurial value.**

(v) Earthworms are used in **vermicomposting.**

10. How do you distinguish between dorsal and ventral surfaces of earthworm?

Ans. **(i)** Dorsal surface is more darker in colour due to porphyrin pigment.

(ii) Dorsal surface has a dark line (dorsal blood vessel) and dorsal pores.

(iii) Female gonopore (on 14th segment) and male gonopores (on 18th segments) are present on ventrolateral side of the body.

(iv) **Genital papillae** are present on ventrolateral sides of 17th and 19th segments of body.

11. Correct the wrong statements among the following:

(a) In earthworm, a single male genital pore is present.

(b) Setae help in locomotion of earthworm.

(c) Muscular layer in the body wall of earthworm is made up of only circular muscles.

(d) Typhlosole is the part of intestine of earthworm.

Ans. **(a)** In earthworm, a pair of male genital pores are present.

(b) Setae help in locomotion, copulation and coming out of burrow.

(c) Muscular layer in the body wall of earthworm is made up of circular and longitudinal smooth muscles.

(d) Typhlosole is inward projecting fold from dorsal side of a part of intestine of earthworm.

12. Why nephridia in earthworm that are basically similar in structure classified into three types? Mention the names of each.

Ans. Though nephridia of earthworm are similar in their basic structure but are classified into three types on the basis of their position:

(i) **Pharyngeal nephridia** occur in 3 pairs of groups, one pair in each of 4th, 5th and 6th segment of body.

(ii) **Integumentary nephridia** attached on inner surface of skin in all segments except first two, clitellar and last segments of body.

(iii) **Septal nephridia** attached on both the sides of intersegmental septa from 15th to last segment of body.

13. Common name of some animals are given in Column A, write their scientific name in Column B:

Column A	Column B
(a) Tiger	_____
(b) Peacock	_____
(c) Housefly	_____

Ans. **(a)** *Panthera tigris;* **(b)** *Pavo cristatus;* **(c)** *Musca domestica.*

14. Complete the following statements:

(a) In Cockroach grinding of food particle is performed by _____

(b) Malpighian tubules help in removal of _____

(c) Hind gut of Cockroach is differentiated into _____

(d) In Cockroach, blood vessels open into spaces called _____

Ans. **(a)** Gizzard;

(b) Nitrogenous wastes (uric acid);

(c) Ileum, colon and rectum;

(d) Sinuses or lacunae (Haemocoel).

15. Mention special features of eye in cockroach.

Ans. **(i)** Cockroach has one pair of kidney-shaped **compound eyes** on head.

(ii) Each compound eye is formed of about 2000 visual units called **ommatidia.**

(iii) Each ommatidium is formed of upper focussing **dioptric part** and lower photosensitive **receptive part.**

(iv) Eye is adapted for **mosaic vision** (final image is formed of several images lying side by side).

16. Frog is a poikilotherm, exhibits camouflage and undergoes aestivation and hibernation. How are all these beneficial to it?

Ans. Frog is a poikilothermal or cold-blooded animal. Its body temperature varies with the environmental temperature so can not tolerate very low winter and very high summer temperatures. It defends by:

(i) **Hibernation (Winter sleep)** i.e. goes deep in moist area and consumes less energy by lowering its metabolic rate. So it is period of dormancy in winter.

(ii) **Aestivation (Summer sleep)** i.e. hides under some shaded area temporarily or goes deep in mud for long period. So it is period of dormancy in summer.

(iii) **Camouflaging (or Protective colouration or mimicry)** i.e. changes body colour to blend with the environment so becomes unnoticeable.

17. Write the functions in brief in column B, appropriate to the structures given in column A:

Column A	Column B
(a) Nictitating membrane	(i) _____
(b) Tympanum	(ii) _____
(c) Copulatory pad	(iii) _____

Ans. **(i)** Protects eye from mud in water and hibernation; and dust on land.

(ii) Sound waves vibrate the tympanum which transmits their force to internal ear through ear ossicle of middle ear.

(iii) Helps the male frog to grasp female during amplexus.

18. Write the appropriate type of tissues in column B, according to the functions mentioned in column A:

Column A	Column B
(a) Secretion and absorption	(i) _____
(b) Protective covering	(ii) _____
(c) Linking and supporting framework	(iii) _____

Ans. **(i)** Cuboidal or columnar simple epithelium.

(ii) Stratified epithelium.

(iii) Connective tissue.

19. Using appropriate examples, differentiate between false and true body segmentation.

Ans. **True body segmentation** is found in earthworm and other annelids in which new segments are added in front of anal segment, while **false body segmentation** is found in tape worms in which new segments are added from anterior side of body (neck region) by strobilation (transverse fission).

20. What is special about tissue present in the heart?

Ans. Myocardium of heart is formed of **cardiac muscle fibres** which are characterized by: small, cylindrical and **strified**; uninucleated; with flat **intercalated discs** with many calcium-channels; interconnected by **oblique bridges** and undergo rapid and **rhythmic contraction** but are **non-fatigue**.

D. LONG ANSWER TYPE QUESTIONS

1. Classify and describe epithelial tissue on the basis of structural modifications of cells.

Ans. Hints: **(i)** List main characteristics of epithelial tissue.

(ii) Enlist the position, structure and functions of squamous, cuboidal, columnar, ciliated and glandular epithelia.

(iii) Enlist the position, structure and functions of stratified and transitional epithelia.

Refer Epithelial tissue of the text.

2. Write down the common features of connective tissue. On the basis of structure and function, differentiate between bones and cartilage.

Ans. **(i)** Enlist common features of connective tissue. Refer **Connective Tissue** page no. 15-16.

(ii) Differentiate between bone and cartilages

Refer Table 18 of the chapter and Figs. 33 and 36

3. Comment upon the gametic exchange in earthworm during mating.

Ans. Though earthworm is a **hermaphroditic animal** but always shows cross-fertilisation due to **protandrous** condition. Copulation occurs during rainy season at night. Two earthworms meet along their ventral sides in **head-to-tail position** and then **reciprocal cross-fertilization** (mutual exchange of sperms) occurs. Sperms are stored in spermathecae.

Refer Fig. 67 of the chapter.

4. Explain the digestive system of cockroach with the help of a labelled sketch.

Ans. Refer page no 51 and Fig. 76 of the chapter.

5. Draw a neat and well labelled diagram of male reproductive system of a frog.

Ans. Refer Fig. 102 of the chapter.

HOTS Higher Order Thinking Skills & Brain Twisting

QUESTIONS WITH ANSWERS

Very Short Answer Questions *One mark each*

1. PCT is lined by brush-bordered columnar epithelium. Why?

Ans. Microvilli of columnar cells of PCT increase surface area of selective reabsorption of useful materials from nephric filtrate.

2. Give the location and function of mast cells.

Ans. Mast cells are present in matrix of areolar connective tissue and secrete heparin (an anticoagulant).

3. Which cells of tissues do not have division power and why?

Ans. Muscle cells and neurons do not have division power due to absence of centrioles.

4. Name a calcified cartilage. Why it is present in frog but not in man?

Ans. Suprascapula. It is well developed in frog due to absence of ribs and provides protection to heart and lungs.

5. Croacking sound is louder in male frog than female. Give reason.

Ans. Male frog is with vocal sacs which amplify the sound.

6. Why nerve impulses travel faster in medullated nerve fibres?

Ans. Nerve impulses are conducted in jumping manner in medullated nerve fibres.

7. Why the blood is called river of life?

Ans. Because it helps in transportation of nutrients, oxygen, CO_2, wastes, hormones, etc. inside the body.

8. State two differences between male and female cockroach?

Ans. Male cockroach has anal styles and 3 gonapophyses, while female cockroach has brood pouch and 3 pairs of gonapophyses.

9. What is function of genital papillae in earthworm?

Ans. Genital papillae keep the copulants together during copulation in earthworm.

10. Which corpuscles of blood act as soldiers and scavengers of body?

Ans. Neutrophils as soldiers and monocytes as scavengers of body.

Short Answer Questions *Two marks each*

1. Name the tissue that lines the fallopian tubes. State any one advantage of this tissue being present here.

Ans. Ciliated columnar epithelium. Cilia beat and move egg or zygote towards uterus.

2. Give the number, position and function of copulatory papillae in earthworm.

Ans. These are two pairs of ridges present one pair on ventral side of each of 17th and 19th segment. These bind the copulants during copulation.

3. Differentiate between male frog and female frog.

Ans. Refer Table 33 of Chapter 7.

4. Discuss hearts in earthworm.

Ans. Earthworm has four pairs of hearts out of which two pairs are present in 7th and 9th segments and are called **lateral hearts** and two pairs lie in 12th and 13th segments and are called **latero-oesophageal hearts**. These hearts conduct blood from dorsal vessel to ventral vessel but prevent the backflow of blood due to presence of valves.

5. What will happen when human RBCs are placed in 2% NaCl solution?

Ans. 2.0% NaCl solution is hypertonic to RBCs so the RBCs become crenated due to exosmosis.

6. Differentiate between single-unit and multi-unit smooth muscles.

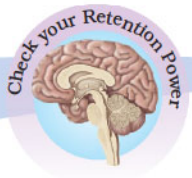
Ans. Refer Table 10 of chapter 7

Short Answer Questions *Three marks each*

1. Describe various types of leucocytes found in blood of man.
2. Name the major classes of plasma proteins and describe their functions.
3. Write short notes on: (i) Clitellum (ii) Setae of earthworm.
4. Write short notes on: (i) Vocal sacs (ii) Amplexusory pads in frog.

Long Answer Questions *Five marks each*

1. Give an account of a neuron.
2. Explain the structure of mammalian bone.
3. Discuss the structure of heart of frog.
4. Describe male reproductive system of cockroach.



QUICK MEMORY TEST

A. Say True or False

Write 'True' or 'False'.

1. Sarcomere is a segment of striated muscle fibre between consecutive Z-lines.
2. Neuroglial cells are packing cells between the neurons.
3. A tendon attaches a muscle to a muscle.
4. Nissl's granules in the cyton are the ribosomes attached on rough endoplasmic reticulum.
5. Haemocyanin is a red coloured respiratory pigment present in the blood of molluscs.
6. Blood platelets are formed from macrophages.
7. Larynx is lined by pseudostratified epithelium.
8. Serum albumin acts as antibody to help in body defence.
9. Bone forming cells are called osteoclasts while bone dissolving cells are called osteoblasts.
10. Histiocytes of areolar connective tissue are phagocytic in action.
11. Ependyma lines the cavities of brain and spinal cord.
12. Nodes of Ranvier occur in non-myelinated nerve fibres.
13. Male gonopores in earthworm are located on 18th segment.
14. Genital papillae are three pairs and are with openings of accessory glands.
15. Clitellum is present around 13th, 14th and 15th segments of earthworm.
16. Arthrodial membranes join the sclerites of exoskeleton of cockroach.
17. Labrum forms the lower lip of mouth parts of cockroach.
18. Anal cerci are present in both male and female cockroach.
19. Spongy part of long bone contains yellow bone marrow which produces blood corpuscles.
20. Both cardiac and smooth muscles are uninucleate and involuntary.

B. Complete the missing links

1. .....epithelium is also called pavement epithelium.
2. Germinal epithelium is located in .....of testes.
3. The non-motile cilia are called ..... .
4. A tendon attaches a ..... to a ..... .
5. ..... is a heterocrine gland.
6. Contractile threads present in sarcoplasm of muscle cells are called ..... .
7. Pseudostratified epithelium lines the ..... tract while transitional epithelium lines the ..... tract.
8. ..... is the structural and functional unit of muscle fibre.
9. Tendon contain bundles of ..... fibres and rows of ..... cells between them.
10. Nerve impulses come to the cell body of a neuron along its ..... and go away from the cell body along its ..... .
11. Bipolar neurons are found in ..... .
12. Brush-bordered cuboidal epithelial cells bear ..... on their free ends.
13. Reticular connective tissue is found in ..... .
14. Suprascapula of frog is a ..... cartilage.
15. Haversian canals of a bone are interconnected by ..... .
16. ..... bands of muscle fibres are made up of protein myosin, while ..... bands are composed of actin.
17. ..... cells help in blood clotting.
18. The large spherical or oval cells present in adipose tissue are ..... .
19. With reference to sex, earthworm is ..... .
20. Cocoon is secreted by ..... .
21. Ist segment of earthworm is called ..... .
22. In earthworm , sperms are stored in ..... .
23. Exoskeleton of cockroach is ..... .
24. ..... . is the visual unit of compound eye of cockroach.
25. Anal ..... are called "ears" of cockroach as have phonoreceptors.
26. Mouth parts of cockroach are ..... type.

27. Only ..... wings are used in flight in cockroach.
28. ..... act as resonators in frog.
29. Sexual embrace of male and female frog is called ..... .
30. Common outlet of faeces, nitrogenous wastes and sex cells in frog is called ..... .

C. Choose the correct alternative

1. **Muscular tissue / Nervous tissue** is a compound tissue.
2. Urinary bladder is lined by **stratified epithelium/ transitional epithelium.**
3. Pancreas is a/an **heterocrine gland/ endocrine gland.**
4. **Skeletal muscles/ cardiac muscles** show rhythmic contraction.
5. A-band of striated muscle fibre is with **myosin/actin/ both myosin and actin proteins.**
6. Tendon is formed of **white fibres/ yellow fibres.**
7. Bone shows **unidirectional/ bidirectional** growth.
8. Antibodies are secreted by **Lymphocytes/Monocytes** of blood.
9. Nissle's granules are rich in **SER/RER.**
10. Dendrons are **afferent/efferent** in nature.
11. Earthworm has **two/four** pairs of lateral hearts.
12. Excretory organs of earthworm are **nephridia/nephrons.**
13. Visual units of compound eyes of cockroach are **taenidia/ ommatidia.**
14. Most important respiratory organ of frog is **skin/lungs.**
15. Frog is **ureotelic/uricotelic** in excretion.

Answers QUICK MEMORY TEST

A. Say True or False

1. True; **2.** True; **3.** False; **4.** True; **5.** False; **6.** False; **7.** False; **8.** False; **9.** False; **10.** True; **11.** True; **12.** False; **13.** True; **14.** False; **15.** False; **16.** True; **17.** False; **18.** True; **19.** False; **20.** True.

B. Complete the missing links

1. Squamous; **2.** Seminiferous tubules; **3.** Stereocilia; **4.** Skeletal muscle, bone; **5.** Pancreas; **6.** Myofibrils; **7.** Respiratory, urinary; **8.** Sarcomere; **9.** Collagen (white), fibroblast; **10.** Dendron, axon; **11.** Retina of eye; **12.** Microvilli; **13.** Spleen; **14.** Calcified; **15.** Volkmann's canals; **16.** Dark, light; **17.** Blood platelets/Thrombocytes; **18.** Adipocytes; **19.** Hermaphrodite (monoecious); **20.** Clitellum; **21.** Peristomium; **22.** Spermathecae; **23.** Sclerotized; **24.** Ommatidium; **25.** Cerci; **26.** Biting and chewing ; **27.** Hind; **28.** Vocal sacs; **29.** Amplexus; **30.** Cloacal aperture.

C. Choose the correct alternative

1. Nervous tissue; **2.** Transitional epithelium; **3.** Heterocrine gland; **4.** Cardiac muscles; **5.** Both myosin and actin proteins; **6.** White fibres; **7.** Bidirectional; **8.** Lymphocytes; **9.** RER; **10.** Afferent; **11.** Two; **12.** Nephridia; **13.** Ommatidia; **14.** Skin; **15.** Ureotelic.

REVISION EXERCISES

Very Short Answer Questions

One mark each

1. Give the location of germinal epithelium.
2. Where is Z-line present?
3. Name the protein found in A-band and I-band.
4. Which tissue stores the fat?
5. Name the protein found in white and yellow fibres.

6. Give an example of hyaline and calcified cartilage.
7. Which mineral is most abundantly found in the bone?
8. Give the location of Nissl's granules.
9. What is synapse?
10. Name the sheath of cartilage and bone.
11. Name the most abundant and least abundant type of blood cells.
12. What is sarcomere?
13. Name the tissue that lines intesinal mucosa and give its advantage.
14. Give the function of histiocytes.
15. Provide one word for the abnormal rise in total count of RBCs.
16. Give the location of transitional epithelium.
17. State one difference between simple epithelium and compound epithelium.
18. Name two peculiar properties of muscle fibres.
19. What is sarcoplasmic reticulum?
20. State one difference between single-unit and multi-unit smooth muscles.
21. Why are the smooth muscles called visceral muscles?
22. Why is areolar connective tissue also called loose fibrous connective tissue?
23. Name various types of cells found in the matrix of areolar connective tissue.
24. State one difference between spongy bone and compact bone.
25. Define Haversian system.
26. Why is blood called "river of life"?
27. Name five types of leucocytes of human blood.
28. Define RBC count.
29. Which organ of human body acts as both blood bank and graveyard of RBCs?
30. State one difference between dendron and axon.
31. What are nodes of Ranvier?
32. Which cells secrete the medullary sheath?
33. What are annuli?
34. What is clitellum? Give its function.
35. Give the location of male and female gonopores in earthworm.
36. What are genital papillae? Where are these located?
37. How many are there pairs of spermathecal pores?
38. Which type of mouth parts are found in cockroach?
39. What are sclerites?
40. What are ommatidia?
41. What are tegmina? Give their function.
42. Give one major difference between male cockroach and female cockroach.
43. What are amplexusory pads? Give their function.
44. What are setae? Give their function.
45. Which structures of earthworm are analogous to kidneys of the vertebrates?
46. What are chloragogen cells? Give their function.
47. Why does self-fertilization not occur in earthworm?
48. Name the digestive glands of cockroach.
49. Define tracheal intercom.
50. What are gonapophyses in cockroach? Give their function.
51. Name the hormones secreted by corpora cardiaca and corpora allata.
52. Define spawn.
53. Why is croaking louder in male frog?
54. Name two types of respiratory muscles in frog.
55. Define amplexus.

ANSWERS

1. Seminiferous tubules; **2.** At the centre of I-band; **3.** Myosin, actin; **4.** Adipose tissue; **5.** Collagen and elastin protein; **6.** At the end of limb bone, suprascapula; **7.** Calcium phosphate; **8.** In neuroplasm of cyton; **9.** Juxtaposition of axon and dendron of adjacent neurons; **10.** Perichondrium and periosteum; **11.** Neutrophils, Basophils; **12.** Structural and functional unit of myofibril and is formed of one complete A-band and half I-band on each side; **13.** Brush-bordered columnar epithelium. The microvilli increase the surface area of absorption of nutrients; **14.** Act as phagocytes; **15.** Polycythaemia; **16.** Lines urinary bladder and ureters; **17.** Simple epithelium is unilaminar, while compound epithelium is multilaminar; **18.** Excitability and conductivity; **19.** A network of SER present in sarcoplasm of muscle fibre; **20.** Single-

unit muscles contract as a single unit, while multi-unit muscles contract separately; **21.** As are found in the wall of visceral organs; **22.** Bundles of white fibres and yellow fibres are loosely arranged; **23.** Mast cells, histiocytes, fibroblasts, chromatophores, plasma cells, mesenchymal cells, etc.; **24.** Spongy bone is with red bone marrow but no regular haversian system while compact bone has yellow bone marrow and is with regular haversion systems; **25.** A haversian canal together with its lamellae, lacunae and canaliculi forms a haversian system; **26.** Transports the materials in side the body; **27.** Neutrophils, Basophils, Eosinophils, Monocytes and Lymphocytes; **28.** Number of RBCs per µl of blood; **29.** Spleen; **30.** Dendrons are small sized and afferent in nature, while axon is long sized and efferent in nature; **31.** Points of discontinuity of medullary sheath of medullated nerve fibres; **32.** Schwann cells; **33. Ring–like grooves** on the body of earthworm which divide the body into metameres ; **34.** A glandular fold surrounding 14th, 15th and 16th segments of body. It secretes **cocoon** ; **35.** Male gonopores lie on **18th segment** and sperms are passed into spermathecae of another worm through them, while female gonopore lies on mid-ventral side of **14th segment** and unfertilized ova are released into cocoon through it; **36.** These are two pairs of ridges having ducts of accessory glands. One pair on each of **17th and 19th segments; 37.** Four; **38.** Biting and chewing type; **39. Chitinous plates** forming exoskeleton of cockroach; **40. Visual units** of compound eyes of cockroach; **41.** Fore wings of cockroach are thick, leathery and act as wing covers ; **42.** Male cockroach has **anal styles** but no brood pouch, while female cockroach has anal cerci and **brood pouch** but no anal styles; **43. Adhesive pads** on ventral side of index fingers of male frog. With their help, male frog grips the female frog; **44.** f-shaped chitinous structures of earthworm which help in locomotion; **45.** Nephridia; **46.** Yellow cells of coelomic fluid which help in excretion and storage of glycogen; **47.** Due to protandrous condition; **48.** Salivary glands, hepatic caecae and midgut lining; **49.** A network of respiratory tubes in cockroach formed by division and redivision of tracheae; **50.** Chitinous structures surrounding gonopores in cockroach . These acts as external genitalia in male and ovipositor in female cockroach; **51.** Corpora cardiaca = Growth hormone, corpora allata = Juvenile hormone; **52.** Mass of eggs released by female frog in water; **53.** Vocal sacs of male frog act as resonators; **54.** Sternohyal and Petrohyal muscles; **55.** Sexual embrace of male and female frogs.

Short Answer Questions

Two marks each

1. What are two chemical substances released into the blood by the mast cells? Specify the effect of each.
2. Describe briefly nature of pseudostratified epithelium. Give one example.
3. Name the kind of epithelium which forms the inner lining of :
   (i) Blood vessels **(ii)** Fallopian tube. Mention one difference between the two.
4. Discuss the normal and abnormal RBC count.
5. Give two peculiar properties of cardiac muscle fibres.
6. Give the location of spermathecal pores in earthworm. What is their function?
7. What is clitellum? Give its function.
8. Differentiate male and female frog.
9. What is nature of exoskeleton of cockroach? List its functions.
10. How do stratified epithelium and transitional epithelium differ from each other?
11. Differentiate between Merocrine, Apocrine and Holocrine glands.
12. Differentiate between tendon and ligament.
13. Differentiate between fibro-cartilage and elastic cartilage.
14. How do axon and dendron differ from each other?
15. Give the position and function of bipolar neurons.
16. What are nephridia? Name the types of nephridia found in earthworm.
17. What are ommatidia? Define mosaic vision of cockroach.
18. Which type of mouth parts are found in cockroach? Name the components of mouth parts.
19. Define metameric segmentation. Where does it occur?
20. Define tracheal intercom. Why is the respiratory system of cockroach more efficient than that of earthworm?
21. What is Bidder's canal? Give its function.
22. What happens when human RBCs are placed in 0.2% NaCl solution? (*Himachal Board 2008*)
23. Give two differences between striated and non-striated muscles. (*Himachal Board 2008*)
24. Give the scientific name of earthworm. What is vermicomposting? (*Himachal Board 2008*)
25. Give scientific name of Indian frog. Give two differences between frog and toad. (*Himachal Board 2008*)

ANSWERS

1. **(i) Heparin** = acts as an anticoagulant and checks blood clotting inside the blood vessels.
   (ii) Histamine = has antiinflammatory and antiallergic reactions.
2. It lines trachea and primary bronchi. In this, cells are of two types : **Tall cells** and **small cells**, all resting on a common basement membrane
3. (i) Endothelium (ii) ciliated columnar epithelium.
   Endothelium is a squamous epithelium.

4. Normal RBC count in man 5-5.5 10^x per µl.**Polycythaemia** = Increase in RBC count. **Anaemia** Decrease in RBC count.
5. Intercalated discs and oblique bridges between the muscle fibres.
6. These are four pairs present on intersegmental grooves, one pair between each of 5/6, 6/7, 7/8 and 8/9th segments. These lead into spermathecae which store the sperms received during copulation;
7. It is a glandular band which surrounds 14th, 15th, and 16th segments of body. It secretes **cocoon** or **ootheca.**
8. Refer Table 33 of chapter 7.
9. Exoskeleton of cockroach is **sclerotized** (formed of chitinous plates called sclerites). It forms a protective, water proof and germ proof coat.
10. Refer Table 5 of the chapter 7.
11.

Character	Merocrine glands	Apocrine glands	Holocrine glands
1. **Mode of secretion**	Only secretion is discharged and no part of gland is lost.	Apical part of gland is lost with the secretion.	Whole gland is lost with the secretion.
2. **Example**	Salivary gland, sweat glands, goblet cells etc.	Mammary glands	Oil glands of skin.

12. Refer Table 15 of the chapter 7.
13. Refer Table 16 of the chapter 7.
14. Refer Table 26 of the chapter 7.
15. **Bipolar neurons** are present in olfactory epithelium of nasal chamber and retina of eye. Each has two nerve processes. One dendron and one axon.
16. **Nephridia** are microscopic , coiled and segmentally - arranged excretory and osmoregulatory structures of earthworm. There are three types of nephridia: pharyngeal nephridia, septal nephridia and integumentary nephridia.
17. **Ommatidia** are visual units of compound eyes of cockroach. In mosaic vision, final image is formed of a number of small images lying side by side.
18. Cockroach has **biting and chewing type mouth parts.** These include labrum, one pair of each of mandibles and first maxillae, labium and hypopharynx.
19. In **metameric segmentation,** external division of body by annuli corresponds with the internal division of coelom of septa. It is found in annelids e.g. earthworm.
20. In cockroach **tracheal intercom** is the network of branches formed by division and redivision of tracheae inside the body. Their finest branches are **bronchioles** which end into the body cells so oxygen directly goes to the body cells and blood has no role in transportation of oxygen.
21. **Bidder's canal** is present inside the kidneys of male frog and receives the sperms from the testis by means of fine and ciliated tubules called vasa efferentia. It conducts the sperms to ureter through transverse collecting tubules.
22. 0.2% NaCl solution is hypotonic to RBCs so the RBCs become swollen due to endosmosis.
23. Striated muscle fibres are multinucleated and have A-and I-bands, while non-striated muscle fibres are uninucleated and donot have bands.
24. Scientific name of earthworm is *Pheretima posthuma*. The process of producing manure from the organic wastes by earthworms is called vermi composting.
25. Scientific name of Indian frog is Rana tigrina. Frog has smooth and moist skin and has webs between the toes, while toad has dry and warty skin and has no webs between the toes.

Short Answer Questions

Three marks each

1. List various characteristics of epithelial tissue.
2. Explain the structure of stratified keratinised squamous epithelium.
3. Distinguish between :
   (i) Single-unit smooth muscle and multi-unit smooth muscle.
   (ii) Myelinated and non-myelinated nerve fibres.
4. List the differences between a bone and a cartilage.
5. Differentiate between :
   (i) Tendon and ligament.
   (ii) Plasma and lymph.

6. Write a note on organs of excretion in a frog.
7. Describe types of multicellular glands on the basis of their shape.
8. Describe transitional epithelium. Where does it occur?
9. Briefly describe the structure of hyaline cartilage.
10. Write a note on Haversian system of bone.
11. Describe structure of a sarcomere with the help of a diagram.
12. Draw a labelled diagram of reproductive organs of earthworm.
13. Differentiate three types of nephridia of earthworm.
14. Draw a labelled diagram of alimentary canal of cockroach.
15. Describe trachea of cockroach and mode of tracheal respiration.
16. Discuss the structures present in the buccopharyngeal cavity of frog.

Long Answer Questions

Five marks each

1. Describe various types of epithelia found in the animals.
2. Enumerate position, structure and function of areolar tissue.
3. Describe the formed components of human blood.
4. List the differences between the striated, smooth and cardiac muscle fibres.
5. Give an illustrated account of cartilage. Mention the important features of different types of cartilages.
6. Describe alimentary canal of an earthworm and its interaction with mankind.
7. Describe the apertures present on the body of earthworm.
8. Describe external characters of cockroach.
9. Briefly describe the circulatory system of earthworm.
10. Explain the urinogenital system of female frog.
11. Which two types of structures are present on thorax of cockroach? Write brief notes on them.

COMPETITION FILE OBJECTIVE TYPE QUESTIONS

A. MULTIPLE CHOICE QUESTIONS (MCQs):

(From AIPMT & Other Competitive Examinations)

1. Which of the following structures is absent in fore limb of frog?
   (1) Brachium (2) Webs (3) Antebrachium (4) Tarsals
   (a) 1, 2 and 3 are correct (b) 1 and 2 are correct (c) 2 and 4 are correct (d) 1 and 3 are correct
   (BHU 2007)
2. ATPase enzyme required for muscle contraction is located in :
   (a) Actinin (b) Troponin (c) Myosin (d) Actin *(Manipal 2007)*
3. Debove's membrane is a layer of :
   (a) Muscular tissue (b) Connective tissue (c) Epithelial tissue (d) All of the above *(BVP 2007)*
4. Achilles tendon is associated with :
   (a) Gluteus muscle (b) Hamstring muscle (c) Quadriceps muscle (d) Gastrocnemius muscle
   (BVP 2007)
5. Among the leucocytes, the largest quantity is of :
   (a) Basophils (b) Neutrophils (c) Eosinophils (d) Monocytes *(BVP 2007)*
6. The lining of intestine and kidneys in humans is :
   (a) Keratinized (b) Brush border (c) Ciliated (d) None of these *(BVP 2007)*
7. Which of the following part of a neuron is covered by fatty sheath?
   (a) Axon (b) Cyton (c) Dendrite (d) Node of Ranvier *(BVP 2007)*
8. Example of embryonic connective tissue is :
   (a) Wolman jelly (b) Wharton's jelly (c) Wright's jelly (d) None of these
   (Haryana PMT 2007)
9. The rupture of urinary bladder is prevented by :
   (a) Pseudostratified epithelium (b) Stratified columnar epithelium
   (c) Stratified cuboidal epithelium (d) Transitional epithelium *(Haryana PMT 2007)*

10. Which one of the following is present in the integument of frog, but not in that of mammals?
(a) Dermis (b) Mucous gland (c) Sweat glands (d) Stratum germinativum
(Haryana PMT 2007)

11. Pylangium in frog is located in :
(a) Conus arteriosus (b) Sinus venosus (c) Atrium (d) Ventricle
(Haryana PMT 2007)

12. Excretory organs of cockroach are :
(a) Malpighian corpuscles (b) Malpighian tubules (c) Hepatic caecae
(d) Metanephridia (e) Green glands ***(Kerala PMT 2007)***

13. Which one of the following is correctly matched regarding earthworm?
(a) Buccal cavity = 1st to 5th segment (b) Stomach = 11th and 12th segment
(c) Typhlosole = 26th to 95th segment (d) Testes = 10th to 14th segment
(e) Gizzard = 6th to 8th segment ***(Kerala PMT 2007)***

14. The male cockroach can be identified by the presence of :
(a) Colleterial glands (b) Green glands (c) Broad abdomen
(d) Anal cerci (e) Anal styles ***(Kerala PMT 2007)***

15. In cockroach, stink gland is found in :
(a) 4th and 5th terga (b) 5th and 6th terga (c) 5th and 6th sterna (d) 4th and 5th sterna
(CPMT 2007)

16. Salivary gland in earthworm is found in :
(a) Dorsal wall of buccal cavity (b) Ventral wall of buccal cavity
(c) Pharyngeal wall (d) None of the above ***(CPMT 2007)***

17. In housefly, pseudotracheae are found in :
(a) Haustellum (b) Rostrum (c) Labellum (d) None of these ***(CPMT 2007)***

18. Which of the following is not the character of *Taenia solium*?
(a) Apolysis (b) Proglottids (c) Metamerism (d) Scolex ***(CPMT 2007)***

19. Body of earthworm is divided into how many metameres or somites?
(a) 60 to 120 (b) 100 to 120 (c) 80 to 120 (d) 120 or more ***(CPMT 2007)***

20. The tailless primate is :
(a) Lemur (b) African baboon (c) Spider monkey (d) Loris ***(Orissa JEE 2007)***

21. Earthworms have no skeleton but during burrowing, the anterior end becomes turgid and acts as a hydraulic skeleton. It is due to :
(a) Gut peristalsis (b) Setae (c) Coelomic fluid (d) Blood **(*CBSE 2008*)**

22. Which one of the following is the true description about an animal concerned?
(a) Rat : Left kidney is slightly higher in position than the right one
(b) Cockroach : 10 pairs of spiracles (2 pairs on thorax and 8 pairs on abdomen)
(c) Earthworm : Alimentary canal consists of a sequence of pharynx, oesophagus, stomach, gizzard and intestine
(d) Frog : Body divisible into three regions – Head, neck and trunk **(*CBSE 2008*)**

23. Which type of white blood cells are concerned with the release of histamine and the natural anticoagulant heparin?
(a) Eosinophils (b) Monocytes (c) Neutrophils (d) Basophils **(*CBSE 2008*)**

24. The most active phagocytic white blood cells are :
(a) Eosinophils and lymphocytes (b) Neutrophils and monocytes
(c) Neutrophils and eosinophils (d) Lymphocytes and macrophages **(*CBSE 2008*)**

25. Which one of the following pairs of items correctly belongs to the category of organs mentioned against it?
(a) Nephridia of earthworm and malpighian tubules of cockroach – Excretory organs
(b) Wings of honey bee and wings of crow – Homologous organs
(c) Thorn of *Bougainvillea* and tendrils of *Cucurbita* – Analogous organs
(d) Nictitating membrane and blind spot in human eye – vestigial organs **(*CBSE 2008*)**

26. Earthworms are :
(a) Ureotelic when plenty of water available (b) Uricotelic when plenty of water available
(c) Uricotelic under condition of water scarcity (d) Ammonotelic when plenty of water available
(*CBSE 2008*)

27. Which one of the following has an open circulatory system?
(a) *Pheretima* (b) *Periplaneta* (c) *Hirudinaria* (d) *Octopus* (***AFMC 2008***)

28. In cockroach, larval and nymphal characters are maintained by :
(a) Ecdysone (b) Salivary glands (c) Parotid glands (d) Juvenile hormone
(***BHU 2008***)

29. The female genital pore of *Pheretima posthuma* is located upon the segment :
(a) 14th (b) 16th (c) 18th (d) 15th (***BHU 2008***)

30. Changes that allow the conversion of larva into adult, is called :
(a) Metagenesis (b) Alternation (c) Metamorphosis (d) Metastasis (***BHU 2008***)

31. In Molluscs, eye is present on a stalk, called :
(a) Ostradium (b) Operculum (c) Osphradium (d) Ommatophore (***BHU 2008***)

32. Which of the following is a transparent tissue?
(a) Tendon (b) Fibro-cartilage (c) Hyaline cartilage (d) All of these (***BHU 2008***)

33. Nerve cells do not divide because they do not have :
(a) Nucleus (b) Centrosome (c) Golgi bodies (d) Mitochondria (***BHU 2008***)

34. Synovial joint is :
(1) Ball and socket joint (2) Pivot joint (3) Hinge joint (4) Cartilaginous joint
(a) 1, 2 and 3 are correct (b) 1 and 2 are correct (c) 2 and 4 are correct (d) 1 and 3 are correct
(***BHU 2008***)

35. Ligament is mainly made up of :
(a) Reticulin (b) Elastin (c) Myosin (d) Collagen
(***Haryana PMT 2008***)

36. Irregular nuclei are present in :
(a) Neutrophils (b) Basophils (c) Eosinophils (d) Monocytes
(***Haryana PMT 2008***)

37. Nucleated RBC is found in :
(a) Man (b) Rat (c) Rabbit (d) Frog (***Haryana PMT 2008***)

38. Connection between axon and dendrite is :
(a) Synapsis (b) Synapse (c) Desmosome (d) Tight junction
(***Haryana PMT 2008***)

39. Hinge joint is present between :
(a) Femur and ulna (b) Humerus and ulna
(c) Femur and pectoral girdle (d) Femur and pelvic girdle (***Haryana PMT 2008***)

40. The number of abdominal segments in male and female cockroach is :
(a) 10, 10 (b) 9, 10 (c) 10, 11
(d) 8, 10 (e) 9, 9 (***Kerala PMT 2008***)

41. In earthworm, the characteristic internal median fold of dorsal wall of intestine, called typhlosole, is present in :
(a) 5 to 9 segments (b) 9 to 14 segments (c) 27 to 95 segments
(d) 15 to last segments (e) 35 to last segments (***Kerala PMT 2008***)

42. Select the correct order of classification of *Rana tigrina* upto genus :
(a) Chordata, Craniata, Amphibia, Gnathostomata, *Rana* (b) Chordata, Craniata, Gnathostomata, Amphibia, *Rana*
(c) Chordata, Amphibia, Gnathostomata, Craniata, *Rana* (d) Chordata, Craniata, Amphibia, Gnathostomata, *Tigrina*
(e) Gnathostomata, Craniata, Chordata, *Rana, tigrina* (***Kerala PMT 2008***)

43. The cloaca in frog is a common chamber for the urinary tract, reproductive tract and :
(a) Alimentary canal (b) Portal system (c) Hepatic portal vessel
(d) Notochord (e) Lymphatic system (***Kerala PMT 2008***)

44. In a myelinated neuron, two adjacent myelin sheaths are separated by gaps called :
(a) Nodes of Ranvier (b) Synaptic cleft (c) Schwann cells
(d) Synaptic knob (d) Neural plate (***Kerala PMT 2008***)

45. Name the type of tissue which forms glands :
(a) Muscular (b) Epithelial (c) Squamous (d) Cuboidal (***Orissa JEE 2008***)

46. In frog and other anuran, the caudal vertebrae are fused to form :
(a) Coccyx (b) Pygostyle (c) Urostyle (d) Prehensile tail
(***Orissa JEE 2008***)

47. Endothelium of blood vessels is made up of :
(a) Simple cuboidal epithelium (b) Simple squamous epithelium
(c) Simple columnar epithelium (d) Simple non-ciliated columnar epithelium
(J and K 2008)

48. The epithelial tissue present on the inner surface of bronchioles and fallopian tubes is :
(a) Cuboidal (b) Glandular (c) Ciliated (d) Squamous ***(CBSE 2009)***

49. Which one of the following is correct pairing of the body part and kind of muscle tissue that moves it?
(a) Heart wall – Involuntary unstriated muscles (b) Biceps of upper arm – Smooth muscle fibres
(c) Abdominal wall – Smooth muscle (d) Iris – Involuntary smooth muscle ***(CBSE 2009)***

50. Compared to blood, our lymph has :
(a) No plasma (b) Plasma without proteins
(c) Less WBCs and no RBCs (d) More RBCs and less WBCs ***(CBSE 2009)***

51. The cell junctions like tight junctions, desmosomes and gap junctions are found in :
(a) Muscular tissue (b) Connective tissue (c) Epithelial tissue (d) Neural tissue ***(CBSE 2009)***

52. The kind of tissue that forms supportive structure in our pinna of external ear, is also found in :
(a) Vertebrae (b) Nails (c) Ear ossicles (d) Tip of the nose ***(CBSE 2009)***

53. Which one of the following correctly describes location of some body parts in the earthworm *Pheretima?*
(a) Two pairs of accessory glands in 16 and 18 segments.
(b) Four pairs of spermathecae in 4-7 segments.
(c) One pair of ovaries attached at septum between 14th and 15th segments.
(d) Two pairs of testes in 10th and 11th segments. ***(CBSE 2009)***

54. If a live earthworm is pricked with a needle on its outer surface without damaging its gut, the fluid that comes out is:
(a) Excretory fluid (b) Coelomic fluid (c) Haemolymph (d) Slimy mucus ***(CBSE 2009)***

55. The cells that maintain marrow cells are called :
(a) Osteocytes (b) Chondrocytes (c) Osteoclasts (d) None of these ***(AFMC 2009)***

56. Histamine is secreted by :
(a) Liver cells (b) Mast cells (c) Nerve cells (d) Kidneys ***(CPMT 2009)***

57. Dark bands are :
(a) A-bands (b) B-bands (c) I-bands (d) Z-lines ***(CPMT 2009)***

58. Which cartilage is present at the joints of long bones?
(a) Calcified (b) Elastic (c) Hyaline (d) Fibrous ***(CPMT 2009)***

59. The area where the medullary sheath is absent in the nerve fibre, is called :
(a) Schwann cells (b) Schwann nodes (c) Nissl's granules (d) Nodes of Ranvier
(CPMT 2009)

60. In earthworm, gizzard is found in :
(a) 8-10 segments (b) 8th segment (c) 27th segment (d) 8-11 segments ***(CPMT 2009)***

61. Heart of cockroach is :
(a) 13-chambered (b) 29-chambered (c) 9-chambered (d) 6-chambered ***(CPMT 2009)***

62. In cockroach, stink gland is found in :
(a) 4th and 5th terga (b) 5th and 6th terga (c) 5th and 6th sterna (d) 4th and 5th sterna
(CPMT 2009)

63. Skeletal muscles are controlled by :
(a) Sympathetic nerves (b) Para-sympathetic nerves
(c) Somatic nerves (d) Autonomic nerves ***(DPMT 2009)***

64. Haversian lamellae are the structures found in :
(a) Hyaline cartilage (b) Fibrous cartilage (c) Bone (d) Myelin sheath
(J and K-CET 2009)

65. The layer of cells forming tissue that appears to be multilayered but actually some of the cells extend from the basement membrane to the surface is :
(a) Simple columnar epithelium (b) Pseudostratified epithelium
(c) Stratified columnar epithelium (d) Stratified cuboidal epithelium ***(J and K-CET 2009)***

66. Epimysium, perimysium and endomysium are found in :
(a) Nerve (b) Blood vessel (c) Striated muscles (d) Uterus ***(BVP 2009)***

67. Bipolar neurons occur in :
(a) Vertebrate embryos (b) Retina of eye (c) Brain and spinal cord (d) Skeletal muscles
(BVP 2009)

68. In which one of the following organisms, its excretory organs are correctly matched?
(a) Humans—Kidneys, sebaceous glands and tear glands
(b) Earthworm—Pharyngeal, integumentary and septal nephridia
(c) Cockroach—Malpighian tubules and enteric caecae
(d) Frog—Kidneys, skin and buccal epithelium **(*CBSE 2010*)**

69. The haemoglobin content per 100 ml. of blood of a normal healthy human adult is :
(a) 5-11 g (b) 25-30 g (c) 17-20 g (d) 12-16 g **(*CBSE 2010*)**

70. Which one of the following pairs of structures is correctly matched with their description?

Structures	Description
(a) Tibia and fibula	Both form parts of knee joint
(b) Cartilage and cornea	No blood supply but do require oxygen for respiratory need
(c) Shoulder joint and elbow joint	Ball and socket type of joint
(d) Premolars and molars	20 in all and 3-rooted

(*CBSE 2010*)

71. Malpighian tubules are analogous to :
(a) Trachea of cockroach (b) Gills (c) Flame cells (d) None of these **(*AFMC 2010*)**

72. Cloacal aperture of frog is used to pass out :
(a) Sperms (b) Faeces (c) Urine (d) All of these **(*AFMC 2010*)**

73. Clitellum of earthworm constitutes segments :
(a) 7, 8 and 9 (b) 10 to 12 (c) 14 to 16 (d) 18 to 20 **(*AFMC 2010*)**

74. Tendons and ligaments are kind of :
(a) Muscular tissue (b) Connective tissue (c) Epithelial tissue (d) Nervous tissue **(*AFMC 2010*)**

75. Which one of the following species of earthworm is not recommended for vermicomposting?
(a) *Eudrilus engeniae* (b) *Eisenia fetidae* (c) *Perionyx excavatus* (d) *Pheretima posthuma* **(*KCET 2010*)**

76. Cockroaches can climb smooth or steep surfaces due to presence of adhesive pads found on the tarsi of their legs. They are called :
(a) Plantulae (b) Tibia (c) Pretarsus (d) Arolium **(*KCET 2010*)**

77. Myelin sheath is formed by :
(a) Ranvier cell (b) Muscle cell (c) Schwann cell (d) Axon **(*UP-CPMT 2010*)**

78. Yolk plug can be seen during which developmental process of frog?
(a) Gastrulation (b) Blastulation (c) Cleavage (d) Organogenesis **(*UP-CPMT 2010*)**

79. Which type of cleavage is found in frog?
(a) Holoblastic (b) Teloblastic (c) Spiral (d) Biradial **(*UP-CPMT 2010*)**

80. What is number of spinal nerves in frog?
(a) 8 Pairs (b) 10 Pairs (c) 11 Pairs (d) 12 Pairs **(*UP-CPMT 2010*)**

81. Haversian canals are present in :
(a) Teeth (b) Muscles (c) Bone (d) Blood **(*UP-CPMT 2010*)**

82. Head of cockroach lacks :
(a) Cardo (b) Gena (c) Trochanter (d) Frons **(*UP-CPMT 2010*)**

83. Skin is a :
(a) Cuboidal epithelium (b) Columnar epithelium
(c) Pseudostratified epithelium (d) Stratified epithelium **(*UP-CPMT 2010*)**

84. Hyaline cartilage does not have :
(a) Fibres (b) Lacunae
(c) Cells (d) Blood capillaries **(*DUMET 2010*)**

85. Which of these is not found in connective tissue?
(a) Hyaluronic acid (b) Basement membrane (c) Collagen fibres (d) Fluid **(*MP-PMT 2010*)**

86. Which type of tissue forms glands?
(a) Epithelial (b) Connective (c) Nervous (d) Muscular **(*MP-PMT 2010*)**

87. Fibroblasts, macrophages and mast cells are present in :
(a) Cartilage tissue (b) Adipose tissue (c) Areolar tissue
(d) Glandular epithelium (e) Compound epithelium **(*Kerala PMT 2010*)**

88. Spermathecae in *Pheretima* are located in the segments :
(a) 14 to 18 (b) 10 to 13 (c) 6 to 10
(d) 6 to 9 (e) 17 to 19 **(*Kerala PMT 2010*)**

89. The outer covering of cartilage is called :
(a) Peritoneum (b) Periosteum (c) Endosteum (d) Perichondrium (***WB-JEE 2010***)

90. Heparin is secreted by :
(a) Kidney cells (b) Blood cells (c) Bone marrow (d) Liver cells (***WB-JEE 2010***)

91. Stereocilia occur in :
(a) Pseudostratified epithelium of trachea (b) Columnar epithelium of stomach
(c) Stratified columnar epithelium of pharynx (d) Pseudostratified columnar epithelium of epididymis
(***AMU 2010***)

92. The lateral hearts in earthworm have :
(a) Four pairs of valves and are situated in segments 7 and 9.
(b) Four pairs of valves and are situated in segments 6 and 8.
(c) Three pairs of valves and are situated in segments 8 and 10.
(d) Two pairs of valves and are situated in segments 6 and 11. (***AMU 2010***)

93. Which statement is incorrect?
(a) Mast cells and basophils secrete histamine and heparin.
(b) Mast cells are smaller than basophils with a bilobed nucleus.
(c) Mast cells are long lived, basophils are short lived.
(d) Mast cells are relatively sessile, basophils are mobile. (***AMU 2010***)

94. In the mouth parts of cockroach, the galea and lacinia form parts of the :
(a) Mandible (b) Maxilla (c) Labium (d) Labrum (***AMU 2010***)

95. One very special feature in the earthworm *Pheretima* is that :
(a) Fertilisation of eggs occurs inside the body
(b) Typhlosole greatly increases the effective absorption area of digested food in intestine
(c) It has a long dorsal tubular heart
(d) The S-shaped setae embedded in the integument are defensive weapons used against the enemies (***CBSE 2011***)

96. Which of the following is correctly stated as it happens in the common cockroach?
(a) Malpighian tubules are excretory organs projecting out from the colon
(b) Oxygen is transported by haemoglobin in blood
(c) Nitrogenous excretory product is urea
(d) The food is ground by mandibles and gizzard (***CBSE 2011***)

97. The ciliated columnar epithelial cells in humans are known to occur in :
(a) Eustachian tube and stomach lining (b) Bronchioles and Fallopian tubes
(c) Bile duct and oesophagus (d) Fallopian tubes and urethra (***CBSE 2011***)

98. Tendons and ligaments are specialised types of :
(a) Areolar tissue (b) Adipose tissue (c) Fibrous C.T. (d) Epithelial tissue (***AMU 2011***)

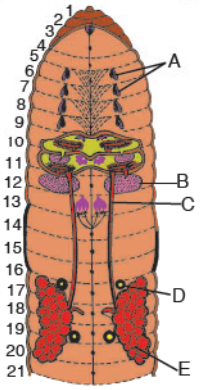
99. Compound eyes are found in :
(a) Frog (b) Earthworm (c) Roundworm (d) Cockroach (***AMU 2011***)

100. Earthworms are hermaphrodites and reproduce primarily by :
(a) Self-fertilisation (b) Cross-fertilisation (c) Asexually (d) All of these (***AMU 2011***)

101. The process of increasing fertility of soil by the earthworms is called :
(a) Worm casting (b) Vermicomposing (c) Compost bedding (d) None of these (***AMU 2011***)

102. In earthworm, setae are present in all the segments except :
(a) First and last segments (b) First and the clitellum
(c) First segment (d) Clitellum and last segments
(e) First, clitellum and last segments (***Kerala PMT 2011***)

103. In the diagram of the reproductive system of earthworm A, B, C, D and E represent:
(a) A = Seminal vesicle, B = Spermathecae, C = Prostate gland, D = Ovary, E = Acessory gland
(b) A = Seminal vesicle, B = Ovary, C = Acessory gland, D = Spermathecae, E = Prostate gland
(c) A = Spermathecae, B = Seminal vesicle, C = Acessory gland, D = Ovary, E = Prostate gland
(d) A = Spermathecae, B = Seminal vesicle, C = Ovary, D = Acessory gland, E = Prostate gland
(e) A = Ovary, B = Seminal vesicle, C = Acessory gland, D = Prostate gland, E = Spermathecae (***Kerala PMT 2011***)



104. About how many times does the nymph of the *Periplaneta americana* undergo moulting before becoming an adult?
(a) 4 (b) 7 (c) 17
(d) 3 (e) 13 (***Kerala PMT 2011***)

105. Fibroblasts, macrophages and mast cells are seen in :
(a) Epithelial tissue (b) Connective tissue (c) Skeletal muscle tissue
(d) Smooth muscle tissue (e) Nervous tissue (***Kerala PMT 2011***)

106. Read the statements with regard to frog. Which of the statement(s) is/are correct and incorrect?
1. Medulla oblongata passes through foramen of Monroe and continues into spinal cord
2. Vasa efferentia are 10-12 in number that arise from testes
3. Ovaries have no functional connections with the kidneys
4. Frogs are uricotelic
(a) 1, 2 and 3 are correct but 4 is incorrect (b) 1 and 2 are correct while 3 and 4 are incorrect
(c) 2 and 3 are correct while 1 and 4 are incorrect (d) 2, 3 and 4 are correct while 1 is incorrect
(e) 3 and 4 are correct while 1 and 2 are incorrect (***Kerala PMT 2011***)

107. Stratified epithelium is found in :
(a) Seminiferous tubule (b) Fallopian tube (c) Nasal cavity (d) Kidney tubule (***J&K CET 2011***)

108. *Pheretima* and its close relatives derive nourishment from:
(a) Sugarcane roots (b) Decaying fallen leaves and soil organic matter
(c) Soil insects (d) Small pieces of fresh fallen leaves of maize (***CBSE 2012***)

109. Compared to those of humans, the erythrocytes of frog are:
(a) Without nucleus but with haemoglobin (b) Nucleated and with haemoglobin
(c) Very much smaller and fewer (d) Nucleated and without haemoglobin (***CBSE 2012***)

110. Select the correct statement from the ones given below with respect to *Periplaneta americana*:
(a) Nervous system located dorsally, consists of segmentally arranged ganglia joined by a pair of longitudinal connectives
(b) Males bear a pair of short thread-like anal styles
(c) There are 16 very long Malpighian tubules present at junction of midgut and hindgut
(d) Grinding of food is carried out only by mouth parts (***CBSE 2012***)

111. What is common between earthworm and *Periplaneta*?
(a) Both have red coloured blood (b) Both possess anal styles
(c) Both have Malpighian tubules (d) Both have segmented body (***AIIMS 2012***)

112. The ingrowth of exoskeleton of head of cockroach is called:
(a) Notum (b) Apodemes (c) Pleura (d) Tentorium (***AFMC 2012***)

113. Which of the following is absent from the coelomic fluid of earthworm?
(a) Salts (b) Haemoglobin (c) Corpuscles (d) Proteins (***AFMC 2012***)

114. Myoglobin is present in:
(a) Heart (b) Kidney (c) Muscles (d) Nerve cells (***AFMC 2012***)

115. A polysaccharide constituent found in the matrix of cartilage is:
(a) Ossein (b) Collagen (c) Chondroitin (d) Hyaline (***AFMC 2012***)

116. In which segment in earthworm, the ovary is present?
(a) 13th segment (b) 14th segment (c) 15th segment (d) 16th segment (***BHU 2012***)

117. Blood-brain barrier is formed by:
(a) Microglial cells (b) Astrocytes
(c) Oligodendrocytes (d) Ependymal cells (***BHU 2012***)

118. Ommatidia serve the purpose of photoreception in:
(a) Cockroach (b) Frog (c) Humans (d) Sunflower (***BHU 2012***)

119. Secretion of tears, milk, sweat and oil are functions of which of the following tissues?
(a) Epithelial (b) Nervous (c) Loose connective (d) Lymphoid (***J&K CET 2012***)

120. Collagen fibres are characteristic of which tissue?
(a) Muscular (b) Epithelial (c) Connective (d) Nervous (***J&K CET 2012***)

121. Which one of the following salts predominates in bone matrix?
(a) Sodium chloride (b) Magnesium phosphate
(c) Calcium phosphate (d) Sodium carbonate (***AMU 2012***)

122. Read the following statements and choose the correct option:
(A) Blood cells secrete fibres of structural proteins called collagen or elastin
(B) Neuroglial cells protect and support the nephrons
(C) Osteocytes are present in spaces called lacunae
(D) Striated muscle fibres are bundled together in a parallel fashion
(E) Biceps are involuntary and striated

(a) C and D alone are wrong (b) B and D alone are wrong
(c) A and C alone are wrong (d) B and C alone are wrong
(e) A, B and E alone are wrong *(Kerala PMT 2012)*

123. Find the wrongly matched pair:
(a) Unicellular glandular cells—Goblet cell (b) Saliva—Exocrine secretion
(c) Fusiform fibres—Smooth muscle (d) Cartilage—Areolar tissue
(e) Intercalated discs—Cardiac tissue *(Kerala PMT 2012)*

124. The "thick" filaments in muscles are the polymerised proteins of:
(a) Meromysin (b) Actin (c) Troponin
(d) Tropomysin (e) Keratin *(Kerala PMT 2012)*

125. In a muscle, the functional unit of contraction is:
(a) I-band (b) A-band (c) H-zone
(d) I-band with a Z-line (e) Portion of myofibril between two successive Z-lines *(Kerala PMT 2012)*

126. Specialized chemoreceptors located on the anterior part of earthworms are:
(a) Heat receptors (b) Photo receptors (c) Taste receptors
(d) Pressure receptors (e) Auditory receptors *(Kerala PMT 2012)*

127. In cockroaches, digestive juice is secreted by the:
(a) Gizzard (b) Malpighian tubules (c) Crop
(d) Oesophagus (e) Hepatic caeca *(Kerala PMT 2012)*

128. H-Zone in the skeletal muscle fibre is due to:
(a) Absence of myofibrils in central portion of A-band
(b) Central gap between myosin filaments in A-band
(c) Central gap between actin filaments extending through myosin filaments in A-band
(d) Extension of myosin filaments in central portion of A-band *(NEET 2013)*

129. What external changes are visible after the last moult of a cockroach nymph?
(a) Mandibles become broader (b) Anal cerci develop
(c) Both fore and hind wings develop (d) Labium develops *(NEET 2013)*

130. Histology deals with the stduy of :
(a) Structures seen with naked eyes (b) Tissues
(c) Changes in form and structure during development (d) Cell *(AMU 2013)*

131. Most of our cells are surrounded by :
(a) blood (b) fluid equivalent to sea water in salt composition
(c) Interstitial fluid (d) pure water *(AMU 2013)*

132. In cockroaches, the flow of haemolymph is:
(a) Heart → Head haemocoel → Perivisceral sinus → Pericardial sinus → Ostia → Heart
(b) Heart → Pericardial sinus → head haemocoel → Perivisceral sinus → Ostia → Heart
(c) Heart → Head haemocoel → Perivisceral sinus → Ostia → Pericardial sinus → Ostia
(d) Heart → Ostia → Perivisceral sinus → Pericardial sinus → Head haemocoel → Ostia *(AMU 2013)*

133. Choose the correctly matched pair:
(a) Areolar Tissue–Loose connective tissue (b) Cartilage–Loose connective tissue
(c) Tendon–Specialized connective tissue (d) Adipose tissue–Dense connective tissue *(AIPMT 2014)*

134. The terga, sterna and pleura of cockroach are joined by:
(a) Cementing glue (b) Muscular tissues. (c) Arthrodial membrane (d) Cartilage *(AIPMT 2015)*

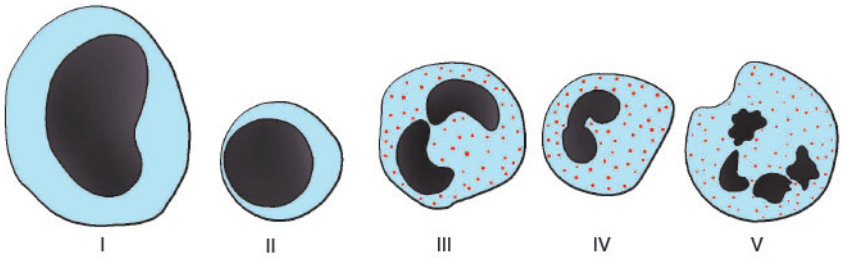
135. Which one of the following is correct?
(a) Plasma = Blood–Lymphocytes (b) Serum= Blood + Fibrinogen
(c) Lymph = Plasma + RBC + WBC (d) Blood = Plasma + RBC + WBC + Platelets *(AIPMT 2015)*

136. The body cells in cockroach discharge their nitrogenous wastes in the haemolymph mainly in the form of :
(a) Ammonia (b) Potassium urate (c) Urea (d) Calcium carbonate
(Re- AIPMT 2015)

137. Intercalated discs occur:
(a) Between neurons (b) Between cardiac muscle fibres
(c) At the junction of muscle and nerve cells (d) In striped muscles *(KCET 2015)*

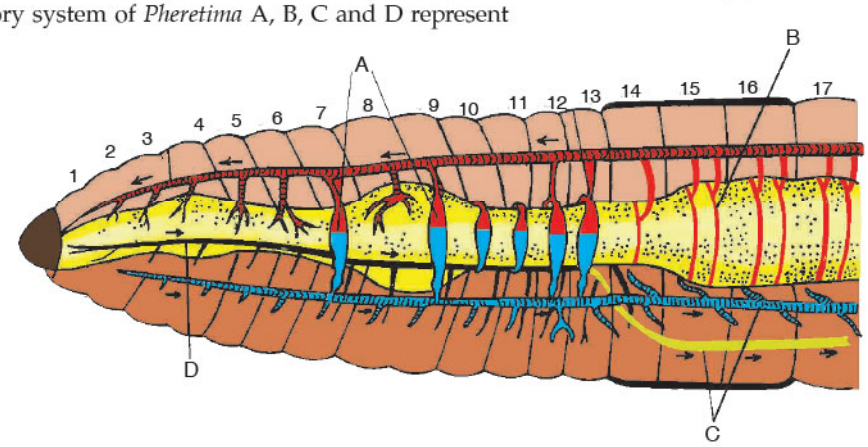
138. Which is not the function of lymph.
(a) Transports RBCs (b) Drains excess tissue fluid
(c) Transports lymphocytes and antibodies (d) Transports absorbed fat *(MH-CET 2015)*

139. Which are the phagocytic cells from given diagram?



(a) I and V (b) I and III (c) I and IV (d) I and II *(MH-CET 2015)*

140. In the circulatory system of *Pheretima* A, B, C and D represent



(a) A – Lateral hearts, B – Subneural vessel, C – Commissural vessel, D = Latero – oesophageal vessel
(b) A – Lateral hearts, B – Latero – oesophageal vessel, C – Subneural vessel, D – Commissural vessel
(c) A – Lateral hearts; B – Commissural vessel; C – Subneural vessel, D – Latero – oesophageal vessel
(d) A – Commissural vessel; B – Lateral hearts; C – Latero – oesophageal vessel D – Sub – neural vessel
(e) A – Commissural vessel, B – Lateral hearts, C – Subneural vessel; D – Latero – oesophageal vessel *(Kerala PMT 2015)*

141. Structure of earthworm which serves as a wedge force open cracks in the soil is :
(a) Peristomium (b) Setae (c) Clitellum
(d) Typhlosole (e) Prostomium *(Kerala PMT 2015)*

142. Which among these is not involved in excretion in cockroaches?
(a) Malpighian tubules (b) Nephrocytes (c) Uricose glands
(d) Maxillary palps (e) Fat body *(Kerala PMT 2015)*

143. Frogs:
(a) are uricotelic (b) have olfactory lobes in mid brain
(c) do not have renal portal system (d) have lymphatic system
(e) have gall bladder which secretes bile *(Kerala PMT 2015)*

144. Most of cartilages in vertebrate embryo are replaced in adult by:
(a) Blood (b) Bones (c) Tendons
(d) Ligaments (e) Muscles *(Kerala PMT 2015)*

145. Which one is specialized connective tissue
(a) Adipose tissue (b) Bones (c) Areolar tissue (d) Fibroblasts
(e) Muscles *(Kerala PMT 2015)*

146. Muscles of heart are:
(a) Striated and voluntary (b) Non- striated and voluntary
(c) Striated, unbranched and involuntary (d) Non-striated and involuntary
(e) Striated, branched and involuntary *(Kerala PMT 2015)*

147. Skeletal muscle fibre is a "syncitium" which means it is:
(a) Made up of many fibres (b) Made up of many proteins
(c) Long and slender (d) Swollen in middle with tapered ends
(e) Multinucleated *(Kerala PMT 2015)*

148. In male cockroach, sperms are stored in which part of reproductive system?
(a) Vas deferens (b) Seminal vesicles (c) Mushroom gland (d) Testes *(NEET Phase-II 2016)*

149. Smooth muscles are:
(a) Voluntary, spindle-shaped, uninucleate (b) Involuntary, fusiform, non-striated
(c) Voluntary, multinucleate, cylindrical (d) Involuntary, cylindrical, striated *(NEET Phase-II 2016)*

150. Which type of tissue correctly matches with its location?
(a) Cuboidal epithelium–Lining of stomach (b) Smooth muscles–wall of intestine
(c) Areolar tissue–Tendon (d) Transitional epithelium–Tip of nose *(NEET Phase-I 2016)*

151. Which of the following features is not present in *Periplaneta americana*?
(a) Metamerically-segmented body (b) Schizocoelom as body cavity
(c) Intermediate and radial cleavage during embryonic development
(d) Exoskeleton formed of N-Acetyl glucosamine *(NEET Phase-I 2016)*

152. Frog's heart when taken out of body continues to beat for some time. Select the best option from the following sentences:
(1) Frog is poikilothermal (2) Frog does not have any coronary circulation
(3) Heart is myogenic in nature (4) Heart is autoexcitable
Options:
(a) Only (3) (b) Only (4) (c) (1) and (2) (d) (3) and (4) *(NEET 2017)*

153. Select the correct route for the passage of sperms in male frogs:
(a) Testes → Bidder's canals → kidneys → vasa efferentia → urinogenital duct → cloaca
(b) Testes → vasa efferentia → kidneys → seminal vesicles → urinogenital duct → cloaca
(c) Testes → vasa efferentia → kidneys → Bidder's canal → ureters → cloaca
(d) Testes → vasa efferentia → kidneys → Bidder's canal → urinogenital duct → cloaca *(NEET 2017)*

154. Nissle's bodies are mainly composed of:
(a) Proteins and lipids (b) Nucleic acids and SER
(c) DNA and RNA (d) Free ribosomes and RER *(NEET 2018)*

155. Match the items given in column-I with those in column-II and select the correct option given below:

Column-I	Column-II
1. Fibrinogen	(i) Osmotic balance
2. Globulin	(ii) Blood clotting
3. Albumin	(iii) Defence mechanism

(a) 1 (iii) 2 (ii) 3 (i) (b) 1 (i) 2 (iii) 3 (ii)
(c) 1 (i) 2 (ii) 3 (iii) (d) 1 (ii) 2 (iii) 3 (i) *(NEET 2018)*

156. Which of the following features is used to identify a male cockroach from a female cockroach?
(a) Presence of boat-shaped sternum on the 9th abdominal segment
(b) Fore wings with darker tegmina
(c) Presence of caudal styles
(d) Presence of anal cerci *(NEET 2018)*

ANSWERS

1. (c);	**2.** (c);	**3.** (b);	**4.** (d);	**5.** (b);	**6.** (b);	**7.** (a);	**8.** (b);	**9.** (d);	**10.** (b);
11. (a);	**12.** (b);	**13.** (c);	**14.** (e);	**15.** (b);	**16.** (c);	**17.** (c);	**18.** (c);	**19.** (b);	**20.** (d);
21. (c);	**22.** (b);	**23.** (d);	**24.** (b);	**25.** (a);	**26.** (d);	**27.** (b);	**28.** (d);	**29.** (a);	**30.** (c);
31. (d);	**32.** (c);	**33.** (b);	**34.** (a);	**35.** (b);	**36.** (a);	**37.** (d);	**38.** (b);	**39.** (b);	**40.** (c);
41. (c);	**42.** (b);	**43.** (a);	**44.** (a);	**45.** (b);	**46.** (c);	**47.** (b);	**48.** (c);	**49.** (d);	**50.** (c);
51. (c);	**52.** (d);	**53.** (d);	**54.** (b);	**55.** (a);	**56.** (b);	**57.** (a);	**58.** (c);	**59.** (d);	**60.** (b);
61. (a);	**62.** (b);	**63.** (c);	**64.** (c);	**65.** (b);	**66.** (c);	**67.** (b);	**68.** (b);	**69.** (d);	**70.** (b);
71. (c);	**72.** (d);	**73.** (c);	**74.** (b);	**75.** (d);	**76.** (a);	**77.** (c);	**78.** (a);	**79.** (a);	**80.** (b);
81. (c);	**82.** (c);	**83.** (d);	**84.** (d);	**85.** (b);	**86.** (a);	**87.** (c);	**88.** (d);	**89.** (d);	**90.** (d);
91. (d);	**92.** (a);	**93.** (b);	**94.** (b);	**95.** (b);	**96.** (d);	**97.** (b);	**98.** (c);	**99.** (d);	**100.** (b);
101. (b);	**102.** (e);	**103.** (d);	**104.** (e);	**105.** (b);	**106.** (c);	**107.** (c);	**108.** (b);	**109.** (b);	**110.** (b);
111. (d);	**112.** (d);	**113.** (b);	**114.** (c);	**115.** (c);	**116.** (a);	**117.** (b);	**118.** (a);	**119.** (a);	**120.** (c);
121. (c);	**122.** (e);	**123.** (d);	**124.** (a);	**125.** (e);	**126.** (c);	**127.** (e);	**128.** (c);	**129.** (c);	**130.** (b);
131. (c);	**132.** (a);	**133.** (a);	**134.** (c);	**135.** (d);	**136.** (b);	**137.** (b);	**138.** (a);	**139.** (a);	**140.** (c);
141. (e);	**142.** (d);	**143.** (d);	**144.** (b);	**145.** (b);	**146.** (e);	**147.** (e);	**148.** (b);	**149.** (b);	**150.** (b);
151. (c);	**152.** (d);	**153.** (d);	**154.** (d);	**155.** (d);	**156.** (c).				

HINTS FOR SOME DIFFICULT MULTIPLE CHOICE QUESTIONS

9. (d): Because transitional epithelium is stretchable.
23. (d): Basophils of blood modify to form mast cells of connective tissue which secrete heparin and histamine.
33. (b): Because nerve cells lose centrioles (which form spindle for cell division) during differentiation.

71. (c): Malpighian tubules of insects and flame cells of flatworms both are excretory in function.

82. (c): Trochanter is a podomere of leg of cockroach.

100. (b): Self-fertilization is not allowed due to protandrous (Testes maturing earlier than ovaries) condition in earthworm.

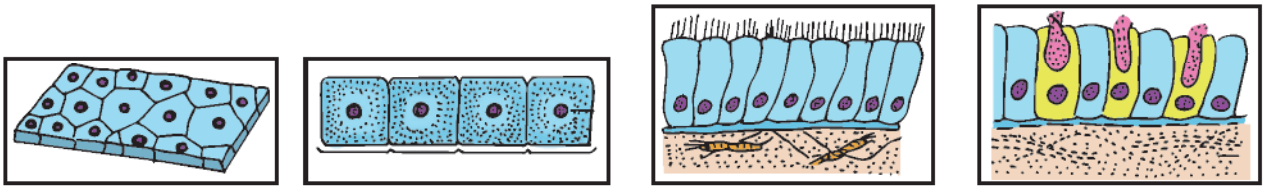
124. (a): In A- band of striated muscle fibre, thick filaments are **myosin filaments** each formed of about 200 meromyosin protein molecules.

142. (d): Maxillary palps are 3-segmented structures of labium of cockroach. These have sensory bristles for smell and taste.

151. (c): Intermediate and radial cleavage is found in echinodermates, hemichordates and vertebrates and not in arthropods .

B. CBSE - PMT (MAIN EXAMINATION) QUESTIONS :

1. Identify A to D and mention one location and one function in the body.

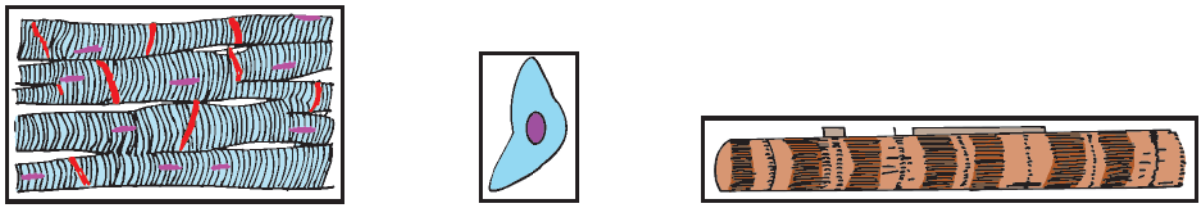


(a) (b) (c) (d) (*CBSE 2005*)

Ans.

Tissue type	Location	Function
(a) **Squamous epithelium**	Bowman's capsule of nephrons and alveoli of lungs.	Ultrafiltration and exchange of gases.
(b) **Simple cuboidal epithelium**	Germinal epithelium of seminiferous tubules of testes and also ovary.	Forms sperms in testes and ova in ovary.
(c) **Ciliated columnar epithelium**	Fallopian tubes of female.	Conduction of ovum/zygote towards uterus.
(d) **Glandular columnar epithelium**	Crypts of Lieberkuhn of intestine.	Secrete enzymes of intestinal juice.

2. (a) Identify the tissues 1, 2 and 3.



(1) (2) (3)

(b) Fill in the blanks :

..... (1) muscles are associated with locomotion and are innervated by ..... (2) nervous system. Whereas ..... (3) muscles are innervated by autonomic nervous system and associated with internal organs and ..... (4) muscles are associated with ..... (5) nervous system associated with pumping of blood . ..... (6) and ..... (7) are uninucleated where as ..... (8) is multinucleated.

The muscle ..... (9) and ..... (10) are involuntary where as ..... (11) muscle is voluntary.

Ans. (a) (1) Cardiac muscle fibres (2) Smooth muscle fibre (3) Striated muscle fibre. (*CBSE 2005*)

(b) (1) Striated; (2) Peripheral; (3) Smooth; (4) Cardiac; (5) Autonomic; (6) Cardiac; (7) Smooth; (8) Striated muscle fibre; (9) Smooth; (10) Cardiac; (11) Skeletal.

3. Differentiate cockroach and frog according to their position to heart and organs of respiration. (*CBSE 2008*)

Ans.

Characters	Cockroach	Frog
1. **Position of heart**	A 13- chambered heart lies in pericardial cavity dorsal to gut.	A 3- chambered heart lies on ventral side between the lungs.
2. **Respiratory organs**	Tracheae.	Skin, buccopharyngeal cavity and lungs.

4. Find out the false statements and correct them by changing only underlined words :

(a) Earthworm has <u>true</u> coelom and is <u>hermaphrodite</u>.

(b) The nitrogenous waste product in human is <u>uric acid</u> and <u>urea</u> in cockroach. (*CBSE 2009*)

Ans. (a) Both the underlined words are correct.

(b) The nitrogenous waste product in human is **urea** and **uric acid** in cockroach.

5. The cells lining blood vessels belong to the category of :

(a) Columnar epithelium **(b)** Connective tissue

(c) Smooth muscle tissue **(d)** Squamous epithelium (*CBSE 2011*)

Ans. (d) For easier exchange of materials between blood and body cells.

6. The type of muscles present in our :

(a) Thigh are striated and voluntary

(b) Intestine are striated and involuntary

(c) Upper arm are smooth muscle fibres fusiform in shape

(d) Heart are involuntary and unstriated smooth muscles (*CBSE 2011*)

Ans. (a).

7. Consider the following four statements (A–D) related to the common frog *Rana tigrina* and select the correct option stating which ones are true (T) and which ones are false (F).

Statements :

A. On dry land, it would die due to lack of O_2 if its mouth is forcibly kept closed for a few days

B. If has four chambered heart

C. On dry land, it turns uricotelic from ureotelic

D. Its life cycle is carried out in pond water.

Options	A	B	C	D
(a)	F	F	T	T
(b)	F	T	T	F
(c)	T	F	F	T
(d)	T	T	F	F

(*CBSE 2011*)

Ans. (a).

8. Which one of the following structure in *Pheretima* is correctly matched with its function?

(a) Setae – defence against predators

(b) Typhlosole – storage of extra nutrients

(c) Clitellum – secretes cocoon

(d) Gizzard – absorbs digested food (*CBSE 2011*)

Ans. (c).

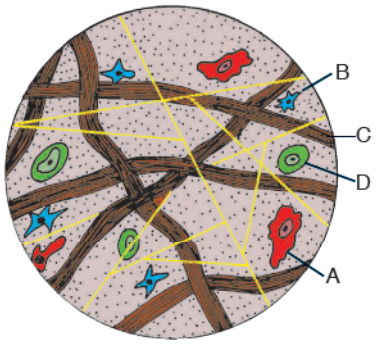
9. Frogs differ from humans in possessing :

(a) Nucleated red blood cells **(b)** Thyroid as well as Parathyroid

(c) Paired cerebral hemispheres **(d)** Hepatic portal system (*CBSE 2011*)

Ans. (a).

10. Given below is the diagrammatic sketch of a certain type of connective tissue. Identify the parts labelled A, B, C and D and select the right option about them:



	A	B	C	D
(a)	Macrophage	Fibroblast	Collagen fibres	Mast cell
(b)	Mast cell	Macrophage	Fibroblast	Collagen fibres
(c)	Macrophage	Collagen fibres	Fibroblast	Mast cell
(d)	Mast cell	Collagen fibres	Fibroblast	Macrophage

(*CBSE 2012*)

Ans. (a)

11. Which one of the following pairs of chemical substances, is correctly categorized?

(a) Calcitonin and thymosin-thyroid hormones.

(b) Pepsin and prolactin-two digestive enzymes secreted in stomach.

(c) Troponin and myosin-complex proteins in striated muscles.

(d) Secretin and rhodopsin-polypeptide hormones. (*CBSE 2012*)

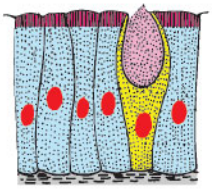
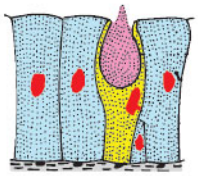
Ans. (c)

12. The supportive skeletal structures in the human external ears and in the nose tip are examples of:

(a) ligament **(b)** areolar tissue **(c)** bone **(d)** cartilage ***(CBSE 2012)***

Ans. (d)

13. The four sketches (A, B, C and D) given below, represent four different types of animal tissues. Which one of these is correctly identified in the options given, along with its correct location and function?

(A)  (B)  (C) (D)

	Tissue	Location	Function
(a)	(B) Glandular epithelium	Intestine	Secretion
(b)	(C) Collagen fibres	Cartilage	Attach skeletal muscles to bones
(c)	(D) Smooth muscle tissue	Heart	Heart contraction
(d)	(A) Columnar epithelium	Nephron	Secretion and absorption ***(CBSE 2012)***

Ans. (a)

C. MATCHING TYPE QUESTIONS :

1. Match the terms in Column A with suitable terms in Column B :

Column A	Column B
(i) Nissl's granules	(a) Elastic cartilage
(ii) Chondrin	(b) Adipose tissue
(iii) Pinna	(c) Goblet cells
(iv) Histiocytes	(d) Smooth muscles
(v) Camel's hump	(e) Intestine
(vi) Visceral organs	(f) Schwann cells
(vii) Afferent nerve process	(g) Cyton
(viii) Microvilli	(h) Dendron
(ix) Mucous	(i) Phagocytosis
(x) Nerve fibres	(j) Cartilage
(xi) Germinal epithelium	(k) Button terminaux
(xii) Synapse	(l) Term tissue
(xiii) Lactic acid	(m) Crypts
(xiv) Bichat	(o) Muscle fatigue

2. Match the terms in Column A with suitable terms in Column B :

Column A	Column B
(i) Genital papillae	(a) Four pairs
(ii) Porphyrin	(b) Wing cover
(iii) Setae	(c) Testes
(iv) Tegmina	(d) Pelage
(v) Lateral sclerites	(e) Ist segment of earthworm
(vi) Vulva	(f) Labium
(vii) Peristomium	(g) 17th and 19th segments
(viii) Hairy coat of rabbit	(h) Amplexusory pad
(ix) Scrotal sacs	(i) Pigment in skin
(x) Spermathecal pores	(j) External genitalia of female rabbit
(xi) Lower lip	(k) Pleura
(xii) Index finger	(l) Locomotion

3. **Match Column A with Column B and select the correct option:**

Column A	Column B
A. Ligamenta flava	(i) Fat depot
B. Costal cartilage	(ii) Plasma cells
C. Phagocytosis	(iii) Reticular cells
D. Adipose tissue	(iv) Connect adjacent vertebra
E. Cartwheel cells	(v) Sternal parts of ribs

(a) A-(iv); B-(v); C-(iii); D-(i); E-(ii); **(b)** A-(iv); B-(i); C-(ii); D-(v); E-(iii);
(c) A-(iii); B-(iv); C-(i); D-(ii); E-(v); **(d)** A-(iii); B-(v); C-(iv); D-(ii); E-(i).

ANSWERS

1. **(i)**-(g); **(ii)**- (j); **(iii)**-(a); **(iv)**-(i); **(v)**-(b); **(vi)**-(d); **(vii)**- (h); **(viii)**-(e); **(ix)**-(c); **(x)**-(f); **(xi)**-(m); **(xii)**-(k); **(xiii)**-(o); **(xiv)**-(l).
2. **(i)**-(g); **(ii)**- (i); **(iii)**-(l); **(iv)**-(b); **(v)**-(k); **(vi)**-(j); **(vii)**- (e); **(viii)**-(d); **(ix)**-(c); **(x)**-(a); **(xi)**-(f); **(xii)**-(h).
3. **(a).**

D. ASSERTION TYPE QUESTIONS:

The following questions consist of two statements each, printed as *Assertion* and *Reason*. While answering these questions, you are required to choose any one of the following four responses :

A. If both *Assertion* and *Reason* are true and *Reason* is a correct explanation of *Assertion*.
B. If both *Assertion* and *Reason* are true but *Reason* is not a correct explanation of *Assertion*.
C. If *Assertion* is true but *Reason* is false.
D. If both *Assertion* and *Reason* are false.

1. **Assertion :** Cardiac muscles contract rapidly like striated muscles but do not undergo fatigue.
   Reason : Cardiac muscles contract rhythmically.
   A **B** **C** **D**
2. **Assertion :** Tendons are very tough and inelastic.
   Reason : Tendons join the muscles to the bone.
   A **B** **C** **D**
3. **Assertion :** Whale has a thick layer of fat, called **blubber**, below its skin.
   Reason : It uses this fat as the source of energy when deep in water.
   A **B** **C** **D**
4. **Assertion :** Serum cannot clot the blood.
   Reason : Serum is obtained from blood plasma minus blood-clotting proteins like prothrombin and fibrinogen.
   A **B** **C** **D**
5. **Assertion :** Synaptic knob of axon has large number of synaptic vesicles.
   Reason : Conduction of nerve impulse is always from axon to dendron.
   A **B** **C** **D**
6. **Assertion :** Cartilage and bone are rigid connective tissue.
   Reason : Blood is a connective tissue in which plasma is matrix. ***(AIIMS 1999)***
   A **B** **C** **D**
7. **Assertion :** Transmission of nerve impulse across a synapse is accompanied by neurotransmitters.
   Reason : Transmission across a synapse usually requires neurotransmitters because there is a small space e.g. synaptic cleft, that separates one neuron from another.
   A **B** **C** **D** ***(AIIMS 1998)***
8. **Assertion :** Cold-blooded animals have no subcutaneous fat layer.
   Reason : Cold-blooded animals use their fat for metabolic processes during hibernation.
   A **B** **C** **D** ***(AIIMS 1997)***

9. **Assertion :** In earthworm, setae show perichaetine arrangement.
Reason : Setae are present in a ring in middle of most of segments.
A B C D *(AIIMS 2000)*

10. **Assertion :** Genital papillae help in copulation in earthworm.
Reason : Genital papillae lie in line with male gonopores.
A B C D *(AIIMS 2003)*

11. **Assertion :** Cockroach is unisexual and shows sexual dimorphism.
Reason : Male cockroach has only anal cerci while female cockroach has anal styles as well.
A B C D *(AIIMS 2005)*

12. **Assertion :** Cockroach has biting and chewing type mouth parts.
Reason : Mandibles have teeth to cut and chew the food in cockroach.
A B C D *(AIIMS 2008)*

13. **Assertion :** Cockroach has two pairs of legs and three pairs of wings.
Reason : Legs are used to jump while wings are used to fly.
A B C D *(AIIMS 2010)*

14. **Assertion :** Mating call is produced by male frog.
Reason : Vocal sacs of male frog act as resonators.
A B C D *(AIIMS 2011)*

15. **Assertion :** In frog, copulatory pads lie on the pollex digit.
Reason : These copulatory pads help in transfer of sperms.
A B C D *(AIIMS 2013)*

ANSWERS

1. A;	2. B;	3. C;	4. A;	5. B;	6. B;	7. A;	8. A;	9. A;	10. B;
11. C;	12. A;	13. D;	14. A;	15. D.					

E. ADDITIONAL MULTIPLE CHOICE QUESTIONS :

1. Which of the following substances, if introduced into the blood stream, would cause coagulation of blood at the site of introduction?
(a) Heparin (b) Fibrinogen (c) Prothrombin (d) Thromboplastin

2. Four healthy people in their twenties got involved in injuries resulting in damage and death of a few cells of the following. Which of the cells are least likely to be replaced by new cells?
(a) Neurons (b) Liver cells (c) Osteocytes (d) Malpighian layer of skin

3. Grey crescent is the area :
(a) At the point of sperm entry into ovum (b) Just opposite to the site of sperm entry into ovum
(c) At the animal pole (d) At the vegetal pole

4. Epithelial cells of intestine involved in food absorption have on their surface :
(a) Pinocytic vesicles (b) Phagocytic vesicles (c) Zymogen granules (d) Microvilli

5. Spermathecae in earthworm is :
(a) For producing sperms (b) For storage of sperms obtained during copulation
(c) Both (a) and (b) (d) None of these

6. 9th pair of cranial nerve in frog is :
(a) Hypoglossal (b) Glossopharyngeal (c) Vagus (d) Trigeminal

7. The adhesive pads (soft pads) present in the legs of cockroach are :
(a) Galea (b) Lacinea (c) Glossa (d) Plantulae

8. Formation of blood is called :
(a) Anaemia (b) Haemolysis (c) Plasmolysis (d) Haemopoeisis

9. Life period of mammalian erythrocytes is :

(a) 120 days (b) 180 days (c) 140 days (d) 220 days

10. Mark the odd one :
(a) Monocytes (b) Lymphocytes (c) Neutrophils (d) Erythrocytes

11. Nerve cells do not divide because they do not have :
(a) Nucleus (b) Golgi body (c) Centrosome (d) Mitochondria

12. Inter-articulated disc is found in :
(a) Muscles of arms (b) Vertebrae (c) Muscles of legs (d) Pubic symphysis

13. Which of the following is phagocytic?
(a) Monocyte (b) RBC (c) Eosinophil (d) Basophil

14. Heparin is secreted by :
(a) Liver (b) Kidney (c) Spleen (d) Blood cells

15. Intervertebral disc consists of a shock absorber connective tissue known as :
(a) Hyaline cartilage (b) Elastic cartilage (c) Fibro- cartilage (d) Reticulo-cartilage
(e) Calcified cartilage

16. In the earthworm dorsal wall of intestine from the 26th to 95th segment forms a median fold called :
(a) Trochophore (b) Typhlosole (c) Clitellum (d) Trachea
(e) Nephridium

17. Vagina, oesophagus and urethra contain which type of tissue?
(a) Ciliated epithelium (b) Columnar epithelium
(c) Simple squamous epithelium (d) Stratified squamous epithelium

18. Intervertebral discs are made of :
(a) Hyaline cartilage (b) Calcified cartilage (c) Fibro-cartilage (d) Elastic cartilage (e) Reticular cartilage

19. In cockroach, enzyme cellulase is produced by :
(a) Saliva (b) Bacteria in midgut
(c) Lining cells of midgut (d) Cellulose is not metabolised

20. Areolar connective tissue joins:
(a) Fat body with muscles (b) Integument with muscles
(c) Bones with muscles (d) Bones with bones

21. Mast cells secrete :
(a) Heparin (b) Myoglobin (c) Histamine (d) Haemoglobin

22. Earthworms are :
(a) Ureotelic when plenty of water is available (b) Uricotelic when plenty of water is available
(c) Uricotelic when conditions of water scarcity (d) Ammonotelic when plenty of water is available

23. Which one of the following has an open circulatory system?
(a) *Pheretima* (b) *Periplaneta* (c) *Hirudinaria* (d) *Octopus*

24. In *Pheretima*, septa are absent between which segments?
(a) 3/4 and 9/10 (b) 4/5 and 8/9 (c) 5/6 and 7/8 (d) 7/8 and 6/7

25. In cockroach, the nymphal characters are maintained by :
(a) Ecdysome (b) Salivary glands (c) Parotid glands (d) Juvenile hormone

26. Which of the following is a transparent tissue?
(a) Tendon (b) Fibrous cartilage (c) Hyaline cartilage (d) All of these

27. In rabbit, end of a long bone is connected to another bone by :
(a) Tendon (b) Ligaments (c) Muscle (d) Cartilage

28. Tendons and ligaments are specialized types of :
(a) Nervous tissue (b) Muscular tissue (c) Epithelial tissue (d) Fibrous connective tissue

29. Female genital pore of *Pheretima posthuma* is located upon the segment :
(a) 14th (b) 16th (c) 18th (d) 15th

30. The type of epithelial cells which line the inner surface of fallopian tubes, bronchioles and small bronchi are known as :
(a) Squamous epithelium (b) Columnar epithelium (c) Ciliated epithelium (d) Cuboidal epithelium

31. Henson's discs are found in :
(a) Myofibrils of striated muscles (b) Myofibrils of unstriated muscles
(c) Myofibrils of heart muscles (d) None of the above

32. Antennae of cockroach function as :
(a) Tactile and Olfactory receptor (b) Gustatoreceptors
(c) Auditory receptor (d) Olfactory receptors

33. Male and female cockroach differ due to presence or absence of :
(a) Anal cerci and anal style (b) Anal cerci (c) Anal style (d) Anal setae

34. Which structure is absent in male cockroach?
(a) Labium (b) Phallomeres (c) Spermatheca (d) None of these

35. In which one of the following preparations are you likely to come across cell junctions most frequently?
(a) Hyaline cartilage (b) Ciliated epithelium (c) Thrombocytes (d) Tendon

36. Which one of the following pairs of structures distinguishes a nerve cell from other types of cells?
(a) Nucleus and mitochondria (b) Vacuoles and fibres
(c) Perikaryon and dendrites (d) Flagellum and medullary sheath

37. The enteronephric nephridia of earthworm are mainly concerned with :
(a) Digestion (b) Respiration (c) Osmoregulation (d) Excretion

38. Striped muscle fibre has :
(a) One nucleus (b) Two nuclei (c) Many nuclei (d) No nucleus

39. Bipolar neurons occur in :
(1) Retina of eye (2) Olfactory epithelium (3) Inner ear (4) Brain
(a) 1, 2 and 3 are correct (b) 1 and 2 are correct (c) 2 and 4 are correct (d) 1 and 3 are correct

40. Cardiac muscles are :
(1) Striated (2) Voluntary (3) Involuntary (4) Non-striated
(a) 1, 2 and 3 are correct (b) 1 and 2 are correct (c) 2 and 4 are correct (d) 1 and 3 are correct

ANSWERS

1. (d);	**2.** (a);	**3.** (b);	**4.** (d);	**5.** (b);	**6.** (b);	**7.** (d);	**8.** (d);	**9.** (a);	**10.** (d);
11. (c);	**12.** (b);	**13.** (a);	**14.** (a);	**15.** (c);	**16.** (b);	**17.** (d);	**18.** (c);	**19.** (d);	**20.** (b);
21. (a);	**22.** (d);	**23.** (b);	**24.** (a);	**25.** (d);	**26.** (c);	**27.** (b);	**28.** (d);	**29.** (a);	**30.** (c);
31. (a);	**32.** (a);	**33.** (c);	**34.** (c);	**35.** (b);	**36.** (c);	**37.** (d);	**38.** (c);	**39.** (a);	**40.** (d);

Chapter Practice Test

Time Allowed : 1½ Hours *Maximum Marks : 35*

1. Lung alveoli are lined by squamous epithelium. Why? (1)
2. Enlist two peculiar features of cardiac muscle fibres. (1)
3. Which cartilage type forms intervertebral discs? (1)
4. State the position and function of clitellum of earthworm. (1)
5. What are vocal sacs? State their function. (1)
6. Differentiate between stratified and transitional epithelium. (2)
7. Enlist the cell types found in matrix of areolar connective tissue and the functions performed by them. (2)
8. Differentiate three types of granulocytes of blood. (2)
9. What is typhlosole? Give its function. (2)
10. Discuss sexual dimorphism in cockroach. (2)
11. Draw a neat and labelled diagram of a sarcomere. (3)
12. Differentiate between a cartilage and a bone. (3)
13. Enlist the functions of plasma of blood. (3)
14. Write a note on compound eye of cockroach. (3)
15. Discuss structure of heart of frog. (3)
16. (a) Draw a neat and labelled diagram of a neuron?
    (b) What are Nissl's granules? Enlist their function.
    (c) Define a synapse. (5)

❑❑❑

To check your performance, see ANSWERS TO CHAPTER PRACTICE TEST at the end of Part I of the book.

UNIT III

CELL : STRUCTURE AND FUNCTION

- CELL : THE UNIT OF LIFE
- BIOMOLECULES
- CELL CYCLE AND CELL DIVISION

CHAPTER 8

CELL : THE UNIT OF LIFE

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CHAPTER PRACTICE TEST 83

CELLULAR NATURE OF LIVINGS

There are about **8.77 millions** of living organisms which include monerans (*e.g.*, bacteria, blue-green algae, mycoplasma, etc.), protists (*e.g.*, slime moulds, protozoans, etc.), fungi (*e.g.*, moulds, mushrooms, etc.), plants (*e.g.*, liverworts, mosses, ferns, cycads, pines and flowering plants) and large variety of animals. Out of these, there are **7.77 million animal species** (especially the arthropods) and 0.5 million plant species. These organisms show great biodiversity not only in shape, size and structure but also in their functioning. But all these living organisms perform certain basic functions in a similar manner and are formed of one or more compartments, called the **cells.** So all these organisms ranging from microscopic organisms like bacteria to gaint organisms like elephants and blue whale are **cellular in nature.** The organisms may be **unicellular** (*e.g.*, *Amoeba*, *Paramecium*, yeast, etc.) or **multicellular** (*e.g.*, plants and animals). Cell is said to be the **smallest structural and functional unit of life** and anything less than a complete cell has no independent existence.

DISCOVERY AND HISTORICAL BACKGROUND OF CELL

- **Aristotle in "Antiquity and Paraceleus in Renaissance"** concluded that all the animals and plants are constituted of a few elements. He is commonly called "**Father of Biology**".
- **Robert Hooke (1665),** an English botanist, observed thin sections of cork under a compound microscope and noticed honey-comb like compartments **(Fig. 1)**. He coined the term **cells** derived from a Latin word *cellula* = a hollow space. He explained his observations in a book namely, **Micrographia.**
- **Anton van Leeuwenhoek (1674),** A Dutch draper was first to observe **living cells** like bacteria from ponds and tartar of teeth, erythrocytes (of a fish), sperms (were called **animalcules**) and protozoans (*e.g. Vorticella*). He is commonly called **animalculist.**
- **N. Grew (1682)** proposed **cell concept** which states that cell is unit of structure of organisms.
- **Robert Brown (1831)** reported the presence of **nucleus** in the root cells of orchids.
- **Dujardin (1836)** reported a semifluidy material around the nucleus of muscle cells and named it **sarcode.**
- **Purkinje (1839)** named this jelly-like material as "**protoplasm**" while protoplasm was called "**physical basis of life**" by **Huxley.**

CELL THEORY

In 1838, **Malthias J. Schleiden,** a German botanist, found that all plants are formed of different types of cells which form the tissues and always have cell wall.

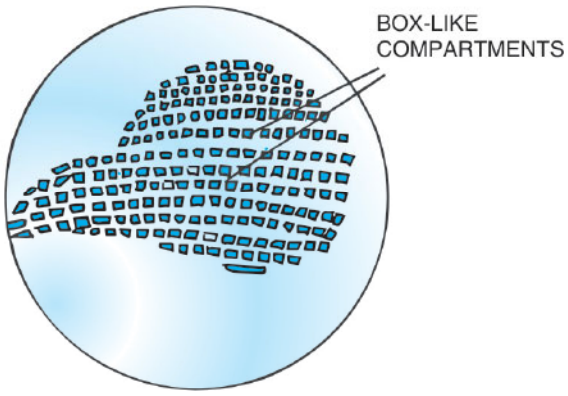


Fig. 1. Microscopic structure of cork as observed by Robert Hooke.

In 1839, **Theodore Schwann,** a British zoologist, observed different types of animal cells. He concluded that the animal cells have thin **plasma membrane** and do not have cell wall as found in plant cells. He proposed **cell hypothesis** which states that bodies of both animals and plants are formed of cells and cellular products.

In 1839, **Schleiden and Schwann** formulated **cell theory.** Important postulates of cell theory are :

1. All the living organisms are made up of cells *i.e.*, they are **morphological and structural units** of living organisms and life exists only in cells.

2. The cells contain **hereditary material** *i.e.*, they are responsible for transmission of characters.

3. New cells are formed *de novo i.e.*, afresh from abiotic materials analogous to crystal formation.

4. Cells are responsible for all the metabolic activities within the living organisms *i.e.*, they are **physiological units** of living organisms.

5. A cell is a small **mass of protoplasm** usually containing a nucleus or nuclear material along with some organelles and is bounded by plasma membrane. A cell organelle cannot survive alone.

Significance

The cell theory was one of the **fundamental generalisation of biology of 19th century.**

Objections to cell theory

1. Schleiden said that new cells were formed inside old ones from the nucleus. This concept was later on found to be wrong by **Hugo Von Mohl** and **K. Nageli.**

2. Another wrong point in the theory was quoted by **Schwann** who said that cell could be spontaneously generated by a process analogous to crystal formation.

3. Rudolf Virchow (1858), a German physiologist, proposed "**Theory of Cell Lineage**" which states "*Omnis cellula a cellula*" which means that new cells are formed from the pre-existing cells and not *de novo.* This was further supported by **Louis Pasteur** (1862) that life originates from pre-existing life (**Biogenesis**).

Exceptions to cell theory

1. Viruses are made up of proteins and one of nucleic acids i.e. DNA or RNA. So they lack protoplasm.

2. Bacteria and blue-green algae which are **prokaryotes** lack well organised nucleus.

3. Coenocytic hyphae of *Rhizopus* or fungus, and alga like *Vaucheria* are multinucleate and aseptate.

Cell principle or cell doctrine. It is the modified form of cell theory due to following reasons:

1. Every living organism is cellular. All the cells have similar basic structure with similar kind of cell organelles, **so cell is structural unit of life.**

2. Different cells perform similar basic functions of life in a similar manner and even have similar control mechanisms, **so cell is functional unit of life.**

3. New cells are formed by the growth and division of pre-existing cells.

THREE FUNCTIONAL REGIONS OF A CELL

A. Plasma membrane. It is outermost, thin, transparent, electron microscopic, elastic, regenerative and semi-permeable membrane. It helps in **exchange of materials** between cytoplasm and extracellular fluid. But in plant cells , outer to plasma membrane, there is a rigid, non-living, protective and supportive layer called **cell wall.**

B. Cytoplasm. It is an amorphous and homogeneous colloidal ground substance present between the plasma membrane and nucleus. It is the seat of both biosynthetic (e.g. protein synthesis) and catabolic (e.g. cell respiration) pathways. It has a number of cytoplasmic structures which are divided into **two categories :**

1. Cell organelles. These are **living** cytoplasmic structures e.g. Endoplasmic reticulum, ribosomes, Golgi body, mitochondria, plastids (only in plants), lysosomes, centriole (only in animal cells), microbodies, etc.

2. Cell inclusions. These are **non-living** structures of cytoplasm e.g. vacuoles.

C. Nucleus. It contains DNA-containing chromosomes. It directs and controls all the cellular activities so is called **director of cell** while its DNA forms the genes which act as units of **heredity and variations.** On the basis of nature of nucleus, the cells are divided into **two categories (Table 1) :**

1. Prokaryotic cells; **2. Eukaryotic cells.**

CELLULAR DIVERSITY

Though all the cells have similar basic structure having three functional regions but they vary greatly in their shape, size, number, life span and activities *e.g.*

1. Cell shape. Shape of cells varies not only in different organisms but also in different parts of same organism **(Fig. 2)**. The shape of the cell may vary with the function they perform **(Table 2) :**

Table 1. Comparison between Prokaryotes and Eukaryotes.

Feature	Prokaryotes (Fig. 6)	Eukaryotes (Fig. 44)
1. Nucleus	No membrane enclosed nucleus. Genetic material consists of one or more folded DNA strands without associated histones.	Enclosed in nuclear membrane. Genetic material present as more than one chromosome. DNA associated with histones (only 40–50% DNA).
2. Cell wall	Cell wall present and contains muramic acid.	Variable, if present, does not contain muramic acid.
3. Organelles	Membrane-bounded organelles not found.	Present.
4. Photosynthetic apparatus	Thylakoids, if present lie freely in the cytoplasm.	Thylakoids, when present, are grouped inside the chloroplasts.
5. Ribosomes	Present free in cytoplasm. Only of 70 S type.	Present free in cytoplasm or associated with ER (80S type). Inside organelles (70S).
6. Centrioles	Absent.	Present in animal cells.
7. Flagella	Sometimes present, made up of single strand.	The flagella if present are 11 stranded.
8. Plasmids and pili	They are found in many prokaryotic cells.	They are absent in eukaryotes.
9. Size range	1–10 µm	10–100 µm.
10. Spindle formation	Mitotic spindle is not formed in cell division.	Mitotic spindle is formed in cell division.
11. Cyclosis	There are no streaming movements of cytoplasm.	Cytoplasm shows streaming movements.

Table 2. Corelation between Cell shape and Cell function.

Cell type	Cell shape	Cell function
1. Human RBCs	Denucleated, circular and biconcave	To transport more oxygen rapidly.
2. WBCs of blood	Amoeboid	To move out of blood capillaries (**Diapedesis**) to engulf the germs.
3. Nerve cells	Long thread-like	For conduction of nerve impulses.
4. Guard cells of stomata	Bean-like	To regulate opening and closing of stomata.
5. Alveolar epithelial cells	Flat and squamous	To allow exchange of gases between air and blood.
6. Smooth muscle cell	Spindle-shaped	For contraction and relaxation.
7. Germ cells of gonads	Cuboidal	Formation of gametes.

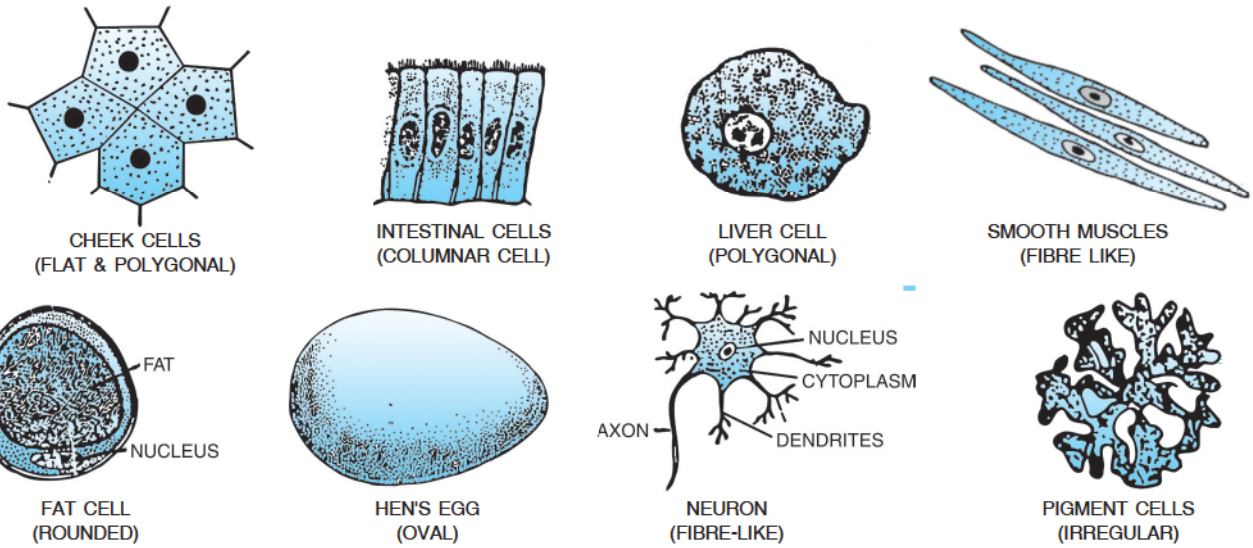


Fig. 2. Diversity in cell shape.

2. Cell size (Fig. 3). The size of cells varies widely in different organisms. The smallest cells are of **pleuro pneumonia-like organism (PPLO–)** ***Mycoplasma gallisepticum*** (*e.g.* 0.1 µm), while largest animal cell is of **ostrich egg** and measures about 170 × 135 mm. In prokaryotes, cell size ranges between 1 to 10 µm while in eukaryotes it ranges between 10 to 100 µm. In plants, largest cell is of green alga, *Acetabularia,* which is one-celled organism and measures about 6-10 cm. Most of the cells of human body are sized between 20 µm and 30 µm but may be as small as 2-3 µm (*e.g.* blood platelets), 7.5 µm (human RBC) to over 3 feet (*e.g.* nerve cell). **Nerve cell is the longest sized cell (about 1 meter) of human body.**

There are **three factors** which govern the cell size :

(i) Cell surface area to volume ratio.

(ii) Nucleo-cytoplasmic ratio.

(iii) Metabolic rate.

(iv) Ability to intake oxygen and nutrients and to expel wastes out of cell.

Relationship between size and function

The **surface area** of the cell membrane is very important since it affects the ability of the cell to exchange the material with its environment. The amount of nutrients required for metabolism depends upon the cell volume. Surface area-volume ratio decreases with increase in size. Thus, a metabolically active cell cannot have large cell volume. **Small bodied organisms have more surface per unit volume than large bodied (Fig. 4).**

So, a large cell responsible for accommodating many large organelles simultaneously reduces the exchange of information and other metabolites through the membrane. Cells overcome this problem by being either cylindrical in shape or by forming infolds or outfolds of membrane.

3. Number. Some organisms are one-celled called **acellular** e.g. *Amoeba, Paramecium,* (earlier were called **unicellular**) and are generally **microscopic** but most of the organisms are multicellular and have indefinite number of cells e.g. a newly--born human infant has about **2×10^{12} cells,** while at maturity the average adult male has about **60×10^{15} cells.** But in some multicellular organisms the number of cells is fixed and is called **eutyly.** Such definite cell numbers are found in certain animals e.g. nematodes like *Ascaris.*

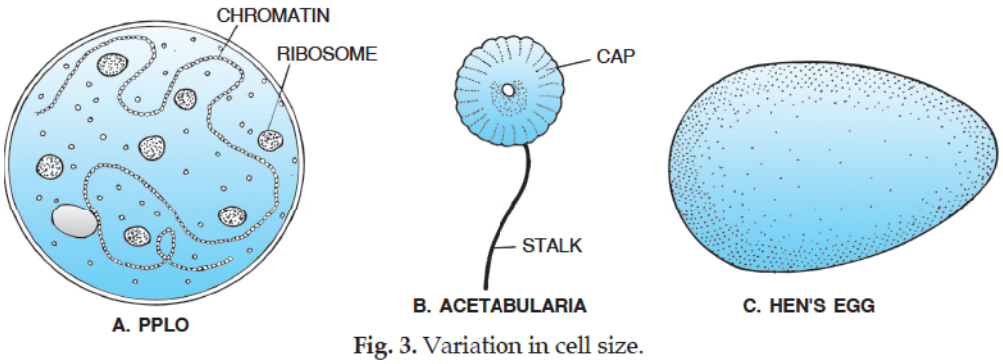


Fig. 3. Variation in cell size.

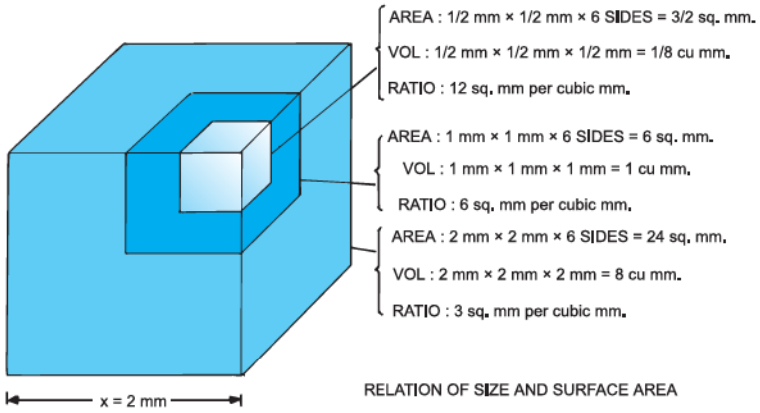


Fig. 4. The effect of size on the surface area.

SUPPLEMENT YOUR KNOWLEDGE

- **Cytology** involves the study of form and structure of cell while **cell biology** involves the study of all the aspects of cells including their structure, biochemistry, physiology, development, etc.
- The cell is basic unit of **biological hierarchy** which includes cells, tissues, organs, organ-systems and organism.
- **Max Schultz (1861) :** Proposed **protoplasm theory** which states that a cell is accumulation of living substance called **protoplasm,** which is bounded by an outer membrane and possesses a nucleus.
- **Kolliker (1862)** coined the term "**cytoplasm**". He called the protoplasm as a polyphasic crystallo-colloidal solution.
- **T. H. Huxley (1868)** described the protoplasm as "**physical basis of life**".

PRACTICE PROBLEMS – CELL AS A UNIT OF LIFE

1. Who coined the word cell?
2. Which scientist called the protoplasm as the physical basis of life?
3. What was the most generalisation of cell biology of 19th century?
4. Who proposed the cell theory?
5. Who stated *Omnis cellula e cellula*?
6. What substance was earlier given the name sarcode?
7. Who coined the word cytoplasm and nucleoplasm?
8. Name the structure and functional unit of life.
9. Name the largest animal cell and plant cell.
10. Name two types of cells.
11. How does the nucleus of a prokaryotic and a eukaryotic cell differ from each other?
12. Give nature of ribosomes in two types of cells.
13. Define cyclosis.
14. List two differences between a plant cell and an animal cell.

ANSWERS TO PRACTICE PROBLEMS

1. Robert Hooke (1665).
2. J. Huxley.
3. Cell theory.
4. M.J. Schleiden and Theodore Schwann (1838-39).
5. Rudolf Virchow (1858).
6. Cytoplasm by F. Dujardin (1835).
7. Strassburger.
8. Cell.
9. (i) Animal cell = Ostrich egg; (ii) Plant cell = *Acetabularia*.
10. Prokaryotic cells and Eukaryotic cells.
11. Prokaryotic cell has incipient nucleus called **nucleoid** while eukaryotic cell has true nucleus.
12. Prokaryotes have 70 S ribosomes while eukaryotic cells have 80 S ribosomes.
13. Streaming movement of cytoplasm.
14. Plant cells have cell wall but no centrosome, while animal cells have centrosome but no cell wall.

PROKARYOTIC CELLS– BACTERIUM

1. Occurrence. Prokaryotes are placed in **Kingdom Monera** so are commonly called **monerans.** These include bacteria, cyanobacteria (Blue-green algae), mycoplasma or PPLO (Pleuro- pneumonia like organisms), spirochaetes and rickettsiae. Among the prokaryotes, bacteria are simplest and commonest type of organisms. The bacteria are found in almost all the places. These have also been reported in the hot springs, beneath the icebergs, in intestine of man, deep in the soil, deep in sea water, etc. These were first discovered by **Anton van Leeuwenhoek (1675).**

2. Size. Bacteria vary greatly in their size. Smallest bacterium is *Dialister* (0.15 to 0.3 µm in diameter) while largest bacterium is *Spirochaete* (about 500 µm). Normally the size of bacillus bacteria lies from 0.3 µm to 15 µm.

3. Shape (Fig. 5). E.J. Cohn recognized following **four basic shapes** of bacteria :

(i) Coccus. These are spherical-shaped bacteria. These may be **monococcus** (single rounded) or **diplococcus** (two rounded) or **tetracoccus** (four rounded) or **streptococcus** (chain of cocci) or **staphylococcus** (bunch of cocci) or **Sarcina** (eight- celled cubical mass).

(ii) Bacillus. These are rod-shaped bacteria. These may be **monobacillus** or **diplobacillus** or **streptobacillus** or **Palisade** (bacteria lying parallel).

(iii) Spirillum. These are spirally coiled and flagellated.

(iv) Vibrio. These are comma-shaped and flagellated.

4. Basic structure of a bacterial cell (Fig. 6)

(i) Cell envelope. It is outermost covering of the cell and provides shape and rigidity to the cell. It also protects from mechanical injuries and bursting

LEARNING PLUS

Examples of Bacteria on the basis of their shape:

- **Cocci :** Monococcus e.g. *M.roseus*
  Diplococcus e.g. *D. pneumoniae*
  Tetracoccus e.g. *Neisseria gonorrhoeae*
  Streptococcus e.g. *S. lactis and S. pyrogenes*
  Staphylococcus e.g. *S. aureus*
  Sarcina e.g. *S. lutea*
- **Bacillus :** Monobacillus e.g. *M. anthracis* & *Lactobacillus lactis Palisade* bacillus e.g. *Corynebacterium diphtheriae* Streptobacillus e.g. *Bacillus cereus*
- **Spirillum** e.g. *S. volutans* and *Treponema pallidum*
- **Vibrio** e.g. *V. cholerae*

or collapsing. Electron microscopic studies revealed that it is formed of **three basic layers;** each of which is specialized to perform specific function:

(a) Glycocalyx. It is outermost layer and varies in its chemical composition and thickness in different bacteria. In most of bacteria e.g. *Escherichia coli* , it is in the form of a loose mucilaginous covering and is called **slimy layer** which protects the bacterium from chemical desiccation, action of phagocytes and helps in adhesion. But is some bacteria, it becomes hard and tough and is called **capsule,** which resists phagocytosis.

(b) Cell wall. It lies inner to glycocalyx and is also rigid, protective and supportive in function. In *E.coli* and other Gram negative bacteria, cell wall is two layered : inner layer of **murein** or **peptidoglycan** which is formed of polysaccharides (like acetylglucosamine-NAG and acetyl muramic acid-NAM) interlinked by β (1 → 4) glycosidic linkages and a tetrapeptide while outer layer is made up of **glycolipids**. In the Gram positive bacteria, the cell wall is single layered and is made up of mainly murein. On the basis of cell wall, bacteria are divided into **two categories** (Table 3) : **Gram positive** and **Gram negative** bacteria.

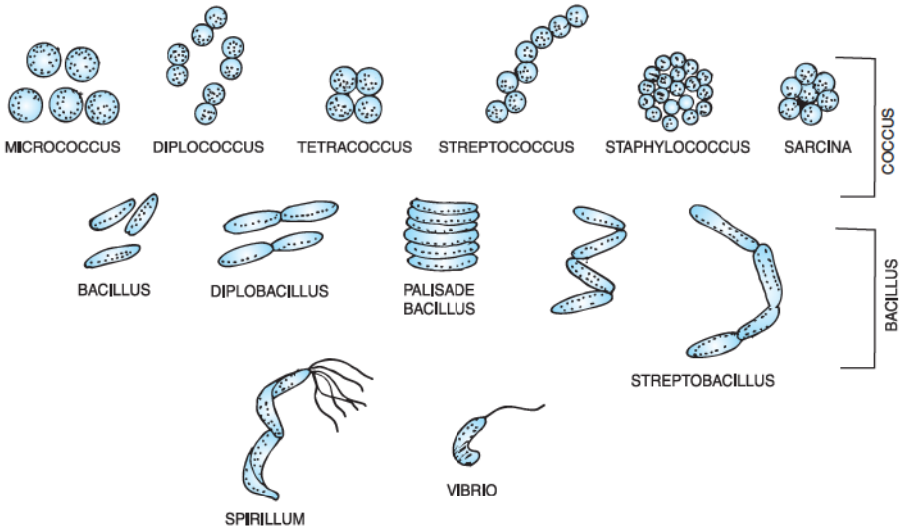


Fig. 5. Different shapes of bacteria.

Table 3. Differences between Gram positive and Gram negative bacteria.

Characters	Gram positive	Gram negative
1. Staining ability	Absorb Gram stain and appear purple coloured.	Do not absorb Gram stain.
2. Cell wall	Monolayered (mainly of murein).	Two layered – Outer of glycolipids and inner of murein.
3. Thickness of cell wall	100- 200 Å so is thicker.	70-120 Å so is thinner.
4. Murein percentage	70 -80%.	10-20% only.
5. Lipids quantity	Less.	More.
6. Mesosomes	Present.	Absent.
7. Pili	Absent.	Present.
8. Examples	*Diplococcus pneumoniae.*	*Escherichia coli.*

R U CURIOUS

Procedure of Gram staining:

(i) Bacteria stained for 30 minutes with purple coloured crystal violet (called Gram stain)

↓

(ii) Washed with water and treated with iodine (acts as mordant)

↓

(iii) Washed with alcohol (decolorizing agent)

↓

(iv) Stained with pink-coloured safranin dye (a counter stain)

↙ ↘

Some bacteria purple-coloured (Gram +ve)

Some bacteria pink-coloured (Gram–ve)

(c) **Plasma membrane.** It is innermost layer of cell envelope. It is thin, transparent and semipermeable membrane. It is lipoproteinous and trilaminar (3-layered) like that of eukaryotes. It is also called **respiratory membrane** as is with components of electron transport chain and enzymes of respiration. It regulates the **exchange of specific materials** between the cytoplasm and extracellular medium. It also has certain **receptor molecules** which help the bacteria to detect and respond to the chemicals.

Mesosomes and chromatophores

● **Mesosomes.** These are characteristic features of prokaryotes and are formed by infolding of plasma membrane in only Gram positive bacteria and may be in the form of **vesicles** or **tubules** or **lamellae.** These help in following functions of bacterium :

– These help in replication of DNA and their separation into daughter cells during binary fission.

– These increase the surface area of respiratory membrane.

– These help in cellular secretion so perform the function of Golgi body of eukaryotes.

– Help in cell wall formation.

● **Chromatophores.** These are internal membrane systems which help in increasing the surface area for increased enzymatic activity and metabolic rate. In cyanobacterial cells, these contain pigments.

(ii) Cytoplasm. It is colourless, translucent and viscous ground substance present inside the cell envelope. It has **reserve food** in the form of glycogen and lipids and 70 S type ribosomes. The ribosomes may be in free form or arranged in the form of helical series on single mRNA strand especially during protein synthesis, called **polyribosomes** or **polysome.** Each 70 S ribosome is 15 nm by 20 nm in size and is formed of two subunits : 50 S and 30 S subunits. But the membrane-bounded cell organelles like mitochondria, ER, Golgi apparatus, plastids, lysosomes, etc. are altogether absent from the cytoplasm.

Cytoplasm of bacteria also has some non-living structures called **inclusion bodies** e.g. reserve food, phosphate granules, etc. while inclusion bodies of cyanobacteria also include cyanophycean granules, glycogen granules and gas vacuoles.

(iii) Nucleoid. It is incipient nucleus of the prokaryotes as a well-organised membrane-bounded true nucleus is absent in them. It has **single and circular chromosome** with no free ends which is formed of double-stranded DNA but is not associated with histones proteins. It is also called **genophore** or **prokaryon or prochromosome**. This circular DNA is extensively looped and coiled with the help of nucleoid proteins. It lacks nucleoplasm, nucleolus and nuclear membrane.

In some bacteria *e.g. Escherichia coli*, additional double stranded circular DNA molecules, called **plasmids,** are also present. Each plasmid contains a few thousand genes, so act as **extra-nuclear genetic material.** The plasmid DNA provides certain peculiar phenotypic characters to these bacteria e.g. **Fertility or sexuality factor, antibiotic resistance,** etc. Fertility factor controls the formation of pili.

5. Flagella. Bacterial cells may bear one or more long, thin and whip-like protoplasmic structures called **flagella**. Each flagellum is **monofibrillar** filament of globular protein **flagellin** molecules. It is differentiated into three parts: **Basal body** or **shaft**, **hook** and **filament**. Basal body lies within the cell wall and is formed of 2M and 2S-rings in the flagellum of Gram negative bacterium while it is formed of one M and one S-ring in the **flagellum** of Gram positive bacterium.

Depending upon the number of flagella, the bacteria are of following types **(Fig. 8)** :

(i) **Atrichous.** Flagellum absent. e.g. cocci bacteria
(ii) **Monotrichous.** With single flagellum, at one end. e.g. *Lactobacillus lactis*
(iii) **Amphitrichous.** With two flagella, one at each end. e.g. *Spirillum serpens*
(iv) **Cephalotrichous.** Two or more flagella at one end. e.g. *Pseudomonas fluorescense*
(v) **Lophotrichous.** Two groups of flagella, one at each end. e.g. *Bartonella bacilliformes*
(vi) **Peritrichous.** Several flagella distributed on whole of bacterium. e.g. *Escherichia coli*

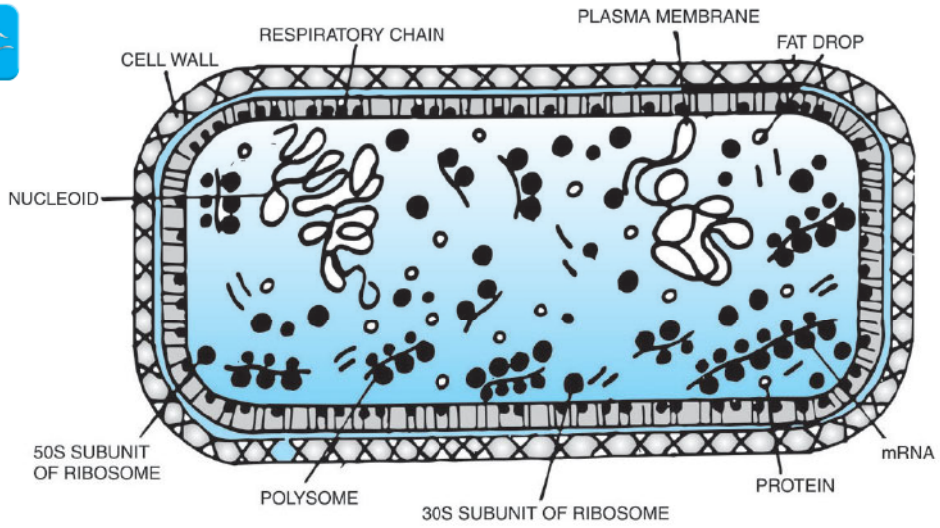


Fig. 6. A prokaryotic bacterial cell

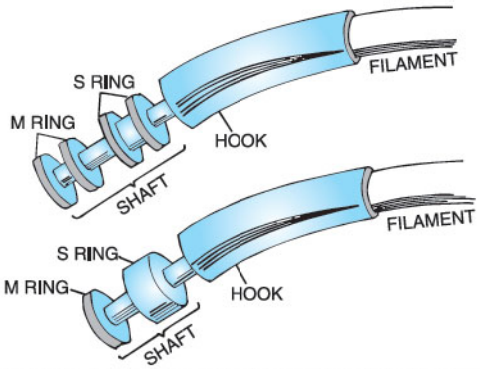


Fig. 7. Flagellum of a prokaryote–Gram negative bacterium (upper), and Gram positive (lower).

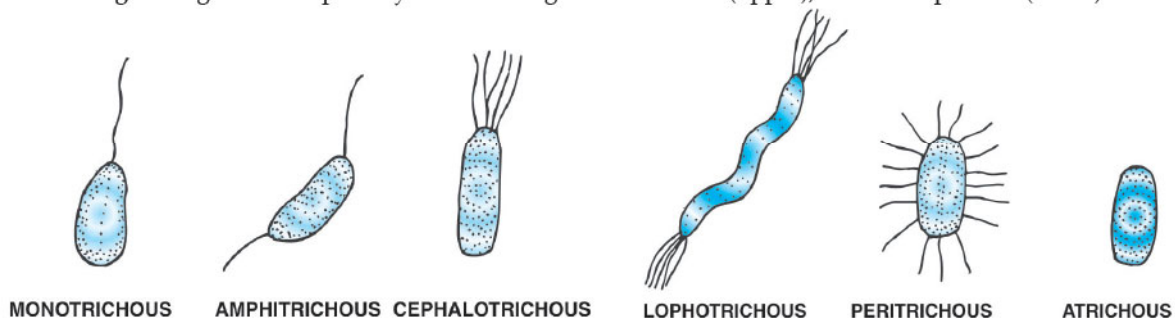


Fig. 8. Flagellation types in bacteria.

6. Pili / Fimbriae. In certain bacteria e.g. *Escherichia coli*, in addition to flagella, there are also minute hair-like, small-sized and narrow structures called **fimbriae** or long tubular structures called **pili,** formed of **pilin** protein. In male *E.coli* these are called **sex pili** as the pili of male bacterium help in attachment to female bacterium during sexual reproduction (conjugation). Fimbriae are not involved in motility but help in adhesion of bacteria to the rocky substratum or to the host's tissues.

Table 4. Differences between Fimbriae and Pili.

Characters	Fimbriae	Pili
1. Occurrence	Both in Gram negative and Gram positive bacteria.	Only in Gram negative bacteria.
2. Number	More, 300-400 per cell.	Less, 1–4 per cell.
3. Size	Shorter and narrow.	Longer and broader.
4. Function	In adhesion.	In conjugation.

COMPETITIVE PLUS

- Cell wall is absent in some prokaryotes e.g. *Mycoplasma.*
- **Gas vacuoles :** These are gas-filled structures present in the cytoplasm of cyanobacteria and purple and green photosynthetic bacteria. These provide buoyancy and help in their floating on water surface.
- Plasmid of male bacterium of *E.coli* has **fertility factor gene** so is called **F-positive** and acts as donor cell during sexual reproduction (conjugation)
- **Episome :** When plasmid becomes associated with nucleoid of bacterium.
- Gram stain is **crystal violet.** Iodine treatment acts as **mordant**
- Tetrapeptide of murein is formed of 4 amino acids: D-Alanine, L-Alanine, D-Glutamic acid and L-Lysine
- **Dodge (1964)** called the dinoflagellates as **mesokaryotes** as the chromosomes are condensed even in interphase, lack the histones and dividing by dinomitosis (nuclear membrane persists and spindle is not formed).

PRACTICE PROBLEMS – PROKARYOTIC CELL

15. Expand the term PPLO.
16. Who first time discovered the bacteria?
17. Name four types of bacteria on the basis of their shape.
18. What are three layers of cell envelope of a bacterium?
19. What is peculiar feature of bacterial cell wall?
20. Why is plasma membrane of bacterium also called respiratory membrane?
21. What are mesosomes?
22. Which type of ribosomes are found in bacterial cytoplasm?

23. Define polysome.
24. Give nature of nucleoid of bacterium.
25. Give the term for the extranuclear rings of DNA molecules.
26. List one difference between flagellum of a bacterial cell and that of a eukaryotic cell.

ANSWERS TO PRACTICE PROBLEMS

15. Pleuro-Pneumonia Like Organism.
16. Anton von Leeuwenhoek.
17. Cocci; Bacillus; Vibrio and Spirillum.
18. Glycocalyx, cell wall and plasma membrane.
19. It is chemically formed of murein or peptidoglycan.
20. Because it has oxidative enzymes and components of ETS of cell respiration.
21. These are infolds of bacterial cell membrane in Gram +ve bacteria.
22. 70 S type ribosomes.
23. When many ribosomes are attached on same mRNA strand.
24. It is formed of single and circular chromosome which is chemically formed of double stranded DNA helix but lacks the histones and other proteins. It also lacks nuclear membrane, nucleoplasm and nuclear envelope.
25. Plasmids.
26. Bacterial flagellum is formed of single strand while that of eukaryote is a microtubular structure having 9+2 arrangement.

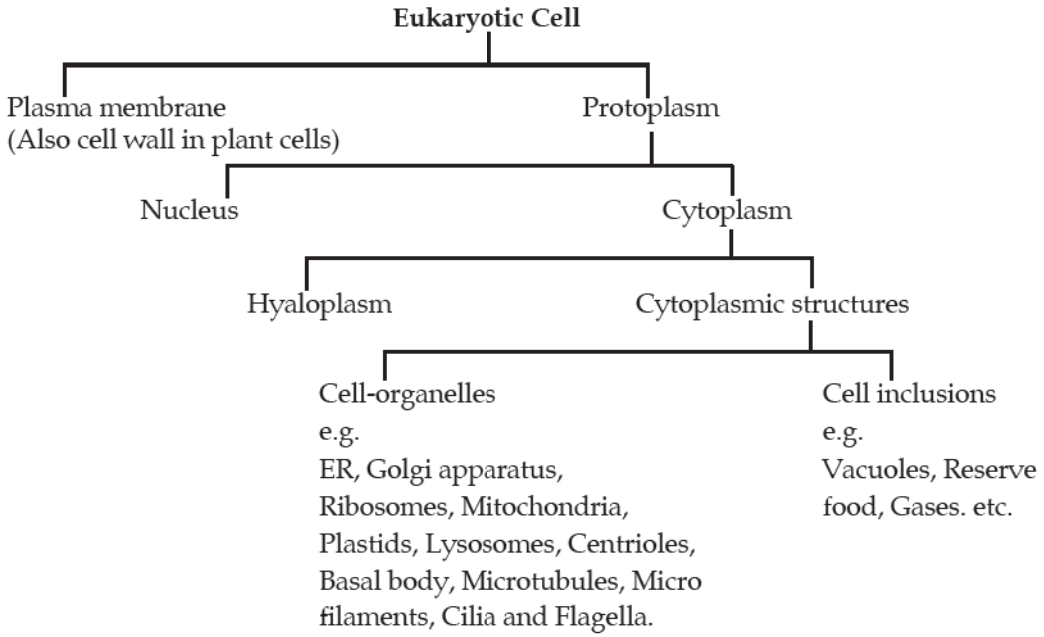
EUKARYOTIC CELLS

1. Occurrence. All the protists, plants, animals and fungi have eukaryotic cellular organisation which differ from the prokaryotic cellular organisation in a number of characters listed in Table 1.

2. **Size**. Eukaryotic cells vary greatly in their size which may be in the range of 10 µm to 500 µm.

3. Generalized structure of Eukaryotic cell (Table 5):

Table 5. Generalized account of Eukaryotic Cell.



I. PLASMA OR CELL MEMBRANE

Every living cell is externally covered by a thin transparent, electron microscopic, elastic, regenerative and semipermeable membrane called **cell membrane** (now called **plasma membrane** or **plasmalemma**). It is present in both prokaryotic and eukaryotic cells. A peculiar functional property of plasma membrane is its **semipermeable nature.**

DEFINITION

The plasma-membrane and all the membranes covering various cell-organelles present inside the cell have same ultrastructure and are collectively called biomembranes because these play vital functions for a living cell.

FUNCTIONS

It is primarily meant to regulate the **exchange of materials** between the cytoplasm and extracellular environment so maintains a **homeostasis** inside the cell. In addition to this, it also helps in synthesis of many macromolecules, response of the cells to a variety of physical and chemical stimuli, etc.

BIOCHEMICAL COMPOSITION OF CELL MEMBRANE

Human RBCs are considered as the best material for the study of biochemical composition. Biochemical studies revealed that the plasma membrane is formed of lipids (about 40%), proteins (about 58-59%) and carbohydrates (about 1-5%).

1. Lipids. Lipid molecules are arranged in a **bilayer** in the cell membrane. It was suggested on the basis of **amphipathic nature** of lipid molecules so the polar or hydrophilic head or glycerol of the phospholipid molecules of two layers are directed in opposite directions and interact with aqueous environment on both sides while non-polar or hydrophobic tails of two layers face each other. This arrangement forms a **water resistant barrier.** Lipids are mainly formed of phospholipids and cholesterol.

Phospholipids constitute about 55 – 75 % of the lipids. More common types of phospholipids are – **lecithin (most abundant) cephalin, phosphatidyl serine, phosphatidyl ionositol** and **phosphatidic acid.** These phospholipid molecules form the structural framework of plasma membrane and allow the faster movement of fat-soluble molecules.

Cholesterol molecules form about 25 -32 % of total lipids and lie between the phospholipid molecules. These stabilize the plasma membrane.

2. Proteins. These constitute about **58–59%** of plasma membrane. The **ratio of proteins to lipids** varies considerable in the plasma membranes of different cell types e.g. these form 52% and 40% respectively in the plasma membrane of human erythrocyte. **Singer (1971)** demonstrated that these membrane -bound proteins are of **two types:**

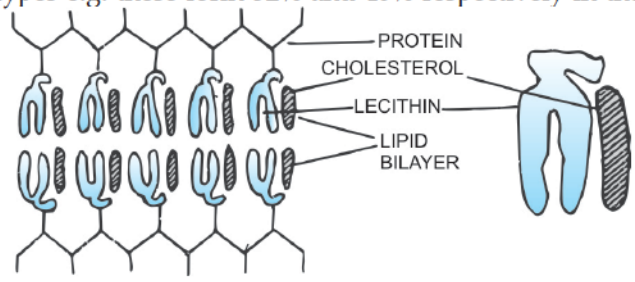


Fig. 9. Arrangement of phospholipid and chloesterol molecules in plasma-membrane.

(i) Peripheral or Extrinsic proteins. These lie outside the outer and inner surfaces of phospholipid bilayer and are loosely attached by weak electrostatic bonds so can be easily separated by mild treatment with salt solutions or some chelators. These form about 30% of the proteins e.g. **Spectrin** (RBC), **Acetylcholinestrase** (Neuron), **ATPase** (mitochondria), etc.

(ii) Intrinsic or Integral proteins. These are partially or completely embedded in the phospholipid bilayer. These are not easily separable. This form about 70 % of the membrane proteins *e.g.* **cytochrome oxidase** (mitochondrial membrane), **rhodopsin** (retinal rod cells), etc.

Structural proteins form the backbone of membrane and provide elasticity and mechanical stability. **Enzymatic proteins** (e.g. Mg^{++}–activated ATPase, Na^{+}-K^{+} activated ATPase, alkaline phosphatase, RNAase, etc.) regulate cellular activities. **Carrier proteins** help in facilitated and active transport. **Hormone receptor proteins** help in the action of quick acting hormones *e.g.* epinephrin.

3. Carbohydrates. These form about **1-5%** of chemical composition. Main carbohydrates reported in plasma membrane are : hexoses, hexosamine, fucose, sialic acid etc. These are present as **glycoproteins** and **glycolipids.**

Glycoproteins of plasma membrane help in cellular recognition, blood grouping, immune response , etc.

STRUCTURAL MODELS OF PLASMA MEMBRANE

1. Sandwich model (Fig. 10). It was proposed by **J. Danielli** and **H. Davson** (1935 A.D.).

(a) Plasma-membrane is a **lipoproteinous** and **trilaminar** or **tripartite membrane.** It is formed of outer and inner denser protein monolayer and a middle transparent phospholipid bilayer. So the **plasma membrane** is a "**protein-lipid-protein sandwich**".

(b) Protein-molecules are **globular** (**α-proteins**) and give stability to the plasma membrane.

(c) Each phospholipid molecule is a **polar molecule** and has two specific ends : **hydrophilic** (**polar** or **glycerol** or **head**) end and **hydrophobic** (**non-polar** or **fatty acid** or **tail**) end. So each phospholipid molecule is an **amphipathic molecule**.

(d) Heads (Glycerols) of phospholipid molecules are directed in opposite directions and are associated with protein molecules, while the tails (fatty acids) of two layers face each other.

(e) Plasma-membrane is a **porous** membrane. It has microscopic pores of 7-10Å.

Drawbacks

(a) It does not explain the functional specificity and variability in the biomembranes.

(b) It does not explain active transport.

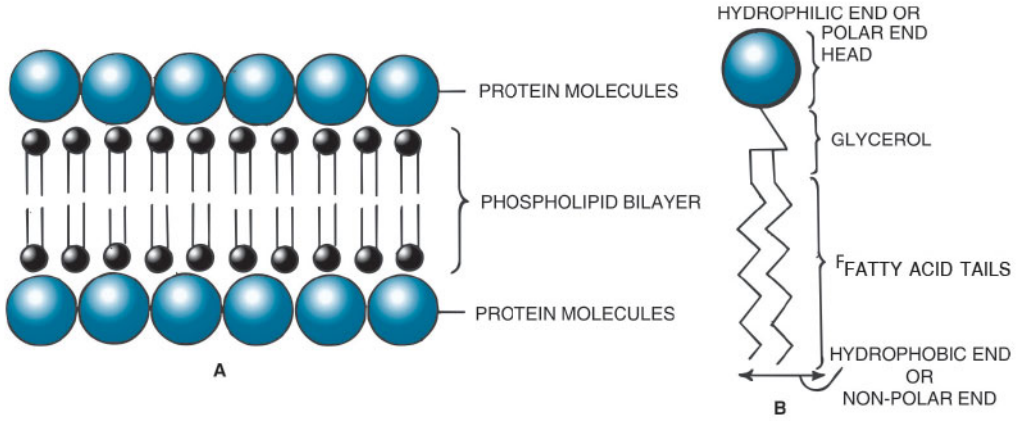


Fig. 10. A. Sandwitch model, **B.** Amphipathic phospholipid molecule.

2. Unit-membrane model (Fig. 11). It was proposed by **J. David Robertson** (1959 A.D.). He studied the ultrastructure of a number of biomembranes of the cell and found that all these membranes are similar in their ultrastructure.

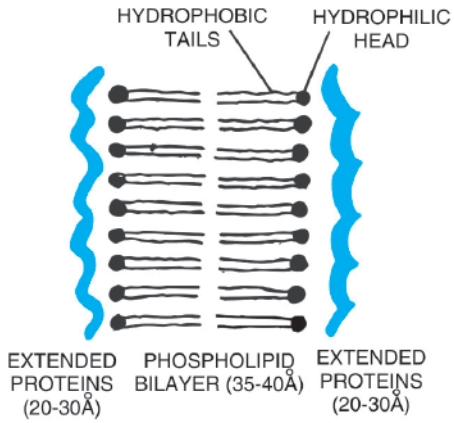


Fig. 11. Robertson's model—Unit membrane model.

He coined the term "**Unit-membrane**". This model states :

(a) Biomembrane is a lipoproteinous and trilaminar.

(b) Protein molecules are **extended (β-proteins or fibrous)** and not globular.

(c) Each phospholipid is a polar molecule with a hydrophilic head of glycerol and hydrophobic tail of two fatty acid chains.

(d) Heads of phospholipid molecules are directed in opposite directions while tails of two layers face each other.

(e) Average thickness of biomembranes is **75-100 Å** in which each protein layer is 20-30 Å while phospholipid bilayer is 35-40 Å.

Both **Danielli and Davson model** (1935) and **Robertson's model** of unit membrane are collectively called **lamellar models.**

3. Fluid-mosaic model (Fig. 12). It was proposed by **S. Jonathan Singer and Garth Nicholson** (1972 A.D.). It is the most accepted model. It states that plasma-membrane is formed of "**protein icebergs in a sea of lipids.**" It is characterised by :

(a) Plasma-membrane is **lipoproteinous** and **trilaminar.**

(b) Phospholipid bilayer is fluidy in nature in which phospholipid molecules show **two types** of movements :

(i) Transition movements (molecules change their position within the same layer).

(ii) Flip-flop movements (molecules of two layers can be interchanged).

(c) Proteins are **globular** and are of **two types :**

(i) Extrinsic or Peripheral proteins.

(ii) Intrinsic or Integral proteins.

Some intrinsic proteins are so large sized that these project on both the surfaces of phospholipid bilayer and are called **tunnel** or **transmembrane proteins.** These act as charged channels for the passage of water-soluble materials.

(d) Each phospholipid molecule is a **polar molecule** and has two specific ends : hydrophilic head of glycerol and hydrophobic tail of two fatty acid chains. So it is an **amphipathic** molecule. Tails protect from water as are hydrophobic.

(e) Heads of phospholipid molecules of two layers are directed in opposite directions while tails of two layers face each other. **This arrangment forms a water resistant barrier.**

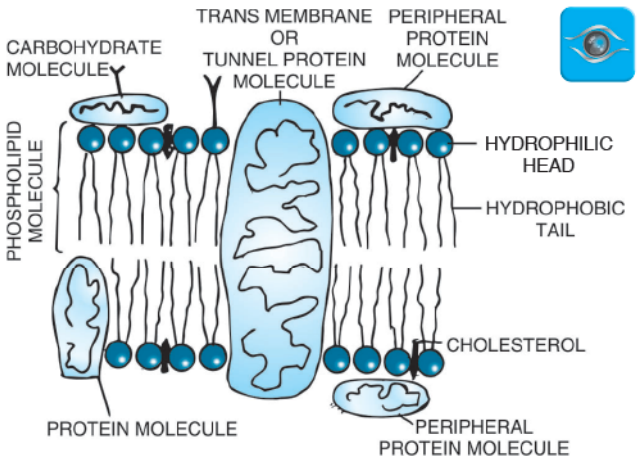


Fig. 12. Fluid-Mosaic model.

(f) Carbohydrate (especially oligosaccharides) are associated with only outer surface of plasma membrane. These either from **glycolipids** or **glycoproteins.**

(g) Cholesterol molecules are present in between the phospholipids. These provide **stability** to animal membranes.

Due to this **quasi-fluid state,** biomembranes can undergo dynamic changes and help in cell growth, formation of intercellular junctions, secretion, endocytosis, cell division, etc. A biomembrane has two distinct surfaces "**cytoplasmic**" and "**exoplasmic**" surfaces because :

(a) Different phospholipids are found in two layers.

(b) Different proteins in two protein monolayers.

(c) Glycoproteins and glycolipids are found only on exoplasmic surface.

PLASMA MEMBRANE OF A BACTERIAL CELL

Though like that of eukaryotic animal cell, plasma membrane of the bacteria is lipoproteinous and trilaminar but differs in certain characteristics :

1. Sterol molecules like cholesterol are absent.

2. Plasma membrane of some bacteria has pentacyclic sterol-like molecules, called **hopanoids.**

3. It has location of enzymes of certain metabolic processes e.g. respiration (enzymes of ETC).

4. Plasma membrane of Gram-positive bacteria is invaginated to form **mesosomes.**

LEARNING PLUS

MODIFICATIONS OF PLASMA-MEMBRANE (FIG. 13)

In order to perform specific functions, the plasma-membrane of a cell shows different modifications :

1. Microvilli. These are finger-like electron-microscopic evaginations found on free surfaces of plasma-membrane of intestinal cells. These form **brush-border.** There are about 3,000 microvilli per intestinal cell. These **increase the surface area** of digestion and absorption.

2. Junctional complexes. Junctional complexes are binding bodies between adjacent cell-membranes. These are of following types :

(a) Interdigitations. These are finger-like processes of adjacent cell-membranes fitting into each other and help in **interlocking.** These also increase the surface area of contact for **exchange of materials.**

(b) Tight junctions. In these junctional complexes, the outer protein layers of adjacent cell-membranes fuse so that there is no intercellular space. These also help in **cell-adhesion.**

(c) Desmosomes. In these, intercellular space increases to 300-500Å and is filled with a cementing material of proteins. Each cell-membrane has a button-like thickening of proteins which gives supporting **tonofibrils** in the cytoplasm. The desmosomes help in **mechanical support** and **cell-adhesion (spot welds).** So called **Transmembrane linkers.**

(d) Gap junctions. In these, adjacent cell-membranes are joined by protein pipes, each having a gap of 20Å. These help in **exchange of materials** (ions and small molecules).

(e) Plasmodesmata. These are cytoplasmic strands which pass through the primary cell-walls of adjacent plant cells. These also help in **exchange of materials.**

3. Glycocalyx. It is an extracellular coat of glycoproteins covering the intestinal cells. It protects the cells from digestive enzymes.

4. Pores. These are small sized (7-10Å) pores in the plasma-membrane which can be opened or closed depending upon metabolic requirements.

5. Endocytotic vesicles. These are pit-like infolds of plasma membrane to receive either a large sized liquid droplet **(pinocytotic vesicle)** or a solid particle **(phagocytotic vesicle)** during the process of **endocytosis.**

6. Sheaths. The plasma membrane also forms sheaths over the axoneme of cilia and flagella.

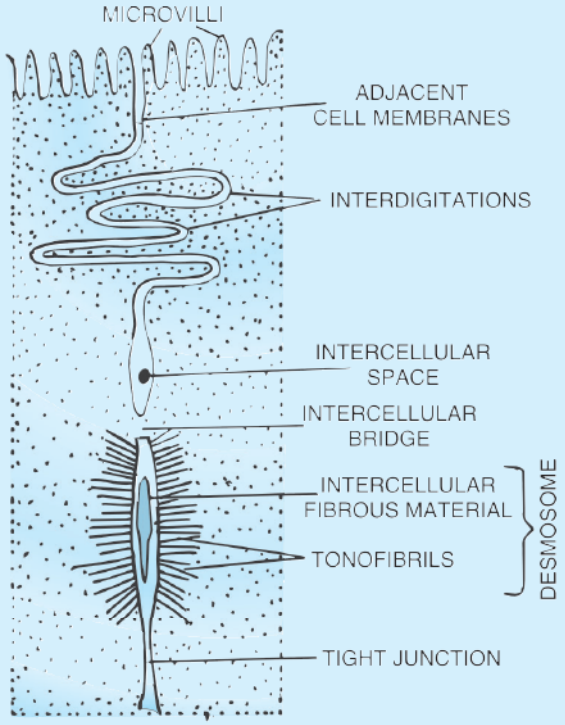


Fig. 13. Modifications of cell-membrane.

ADDITIONAL USEFUL INFORMATIONS ABOUT STRUCTURAL MODELS AND MODIFICATIONS OF PLASMA MEMBRANE FOR COMPETITIVE EXAMINATIONS

- *Nagelli and Cramer (1855) : Gave the term cell membrane.*
- *J.Q. Plowe (1931) : Called cell membrane as plasmalemma.*
- *Amphipathic molecule : A polar molecule having both hydrophilic and hydrophobic ends e.g. Phospholipid and protein molecule.*
- *According to unit membrane model, thickness depends upon relative arrangement of phospholipids and proteins.*
- *Proteins of plasma-membrane provide functional specificity, elasticity and mechanical support.*
- *Glycoproteins of plasma membrane determine antigen specificity of cell. These glycoproteins form major histocompatible complex (MHC) which are of specific type in every individual so act as finger prints of the cell.*
- *Tight junctions are also called zonula occulodens, while desmosomes and terminal bars are respectively called macula adherens and zonula adherens respectively. Gap junction is called nexus.*
- *Lehninger : Described the percentage of extrinsic (30%) and intrinsic (70%) proteins.*
- *Hormone receptor proteins of plasma membrane of target cells act as signal transduction.*
- *Proteins provide structural and functional specificity to plasma membrane.*
- *Phospholipid bilayer arrangement forms a water - resistant barrier and explains the rapid penetration of lipid molecules through the plasma membrane.*
- *Loamosomes : Infolds of plasma membrane found in the fungi. These were reported by Moore and Mclean.*
- *Mesosomes : Infolds of plasma-membrane found in the bacteria. These were reported by Fitz Jammes (1960).*
- *Tranosomes : Found in follicular cells of ovary of birds and have triple unit membrane.*
- *Negative charge to cell membrane is provided by N. Acetyl neuraminic acid (commonly called sialic acid).*
- *Glycophorin : A glycoprotein found in the plasma-membrane of RBC.*
- *Frys and Edidin (1970) : Proved the fluidy nature of biomembranes by cell fusion experiment between mouse cells and human cells.*

R U CURIOUS

DEMONSTRATION OF FLUID NATURE OF CELL MEMBRANE

Fluidity of biomembrane can be demonstrated by a simple experiment (**Fig. 14**). It was proved by **Frey and Edidin** (1970). A human cell was labelled with red fluorescent antibodies and mouse cell was labelled with green fluorescent antibodies. These cells were made to fuse by **somatic hybridization technique**. It was observed that composite cell (also called **heterokaryon**) formed after fusion was half green and half red. After keeping it for some time at 37°C, it was re-examined. It was noticed that green and red colour have fully mixed up. It represented the fluid nature of lipid bilayer in which proteins were moving. If the fused cell kept immediately at 0°C *i.e.*, low temperature, colours fail to mix up because lipids solidify at this temperature.

FUNCTIONS OF PLASMA MEMBRANE

1. It causes **compartmentation** and allows **exchange of materials** between these compartments to maintain constant interval environment.

2. **Protects** the cell from injury.

3. Carrier proteins of plasma membrane help in **active transport.**

4. Plasma-membrane is a **selectively permeable** or **differentially permeable** or **semi-permeable** membrane which regulates the exchange of materials between the cytoplasm and extracellular interstitial fluid. It is a **dynamic membrane** whose semipermeability depends upon a number of mechanisms :

I. PASSIVE TRANSPORT

It is characterized by :

(a) Material moves **along concentration gradient.**

(b) It is **not energy-dependent** so is **slow.**

(c) The substances **cannot be transported completely**.

(d) It is not affected by low temperature, absence of oxygen, presence of cyanides etc.

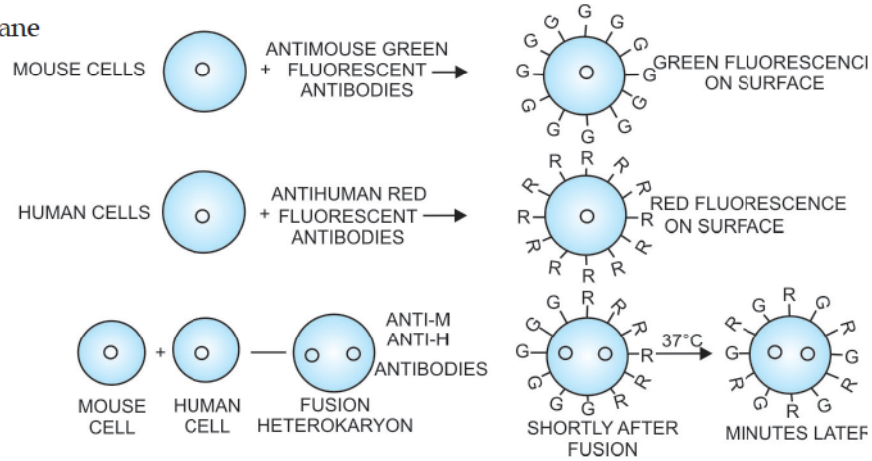


Fig. 14. Experiment to show the fluid nature of cell membrane.

(e) Direction of transport varies so shows **bidirectional transport.** It depends upon direction of concentration gradient.

(f) Carrier molecules may or may not be involved.

The physical processes involve **diffusion** and **osmosis.**

1. Diffusion

Definition. It is the transport of materials (solids, gases or liquids) from a region of higher concentration or electrochemical potential or free energy or diffusion pressure to a region of lower concentration or electrochemical potential or free energy or diffusion pressure due to tendency of their molecules to spread uniformly by their random movements ***(Brownian movements)*** **due to their kinetic energy. Materials may be in the form of molecules, atoms or ions.**

Examples : (a) Diffusion of Non-electrolytes (Fig. 15). When a $CuSO_4$ crystal is placed in a beaker of water, then after some time, water around the crystal becomes blue. This is because the $CuSO_4$ molecules diffuse on all sides until these are uniformly distributed and water becomes uniformly blue. Non-electrolytes always move along their **concentration gradient.**

(b) Diffusion along the pressure gradient (Fig. 16). Gases always diffuse from a region of higher partial pressure to a region of lower partial pressure (**along pressure gradient**) *e.g.* exchange of gases in external respiration at lung alveoli.

Facilitated or carrier-mediated diffusion. Sometimes, diffusion through cell membrane is speedened by some **carrier protein** molecules, called **permeases,** present in the cell membrane, *e.g.* intestinal absorption of fructose and nucleotides. This is called **facilitated diffusion** or **facilitated transport.** It is also not energy dependent so is a type of passive transport. In this, the transportant passes through a channel present inside the carrier protein molecule. It transports polar molecules across the non-polar lipid bilayer of plasma membrane.

Significance of Diffusion

(a) It helps in the **uniform distribution** of substances inside the cytoplasm.

(b) The **pheromones** of the animals diffuse into the air to reach and **stimulate other animals of same species** to signal for sexual act, territory marking, etc.

(c) The scented flowers release their odoriferous chemicals in the air. These chemicals diffuse into the air to **attract pollinating agents.**

(d) It helps in **respiratory gas exchange.**

(e) Transpiration in plants occurs by diffusion.

2. Osmosis

Definition. It is the transport of water or any other solvent molecules from a region of lower concentration (or higher water potential) to a region of higher concentration (or lower water potential) through a semipermeable membrane. It does not allow the movement of solute particles.

Diffusion rate is directly proportional to the concentration difference across the cell membrane and temperature, but is inversely proportional to the density of the medium and molecular weight of diffusing particles.

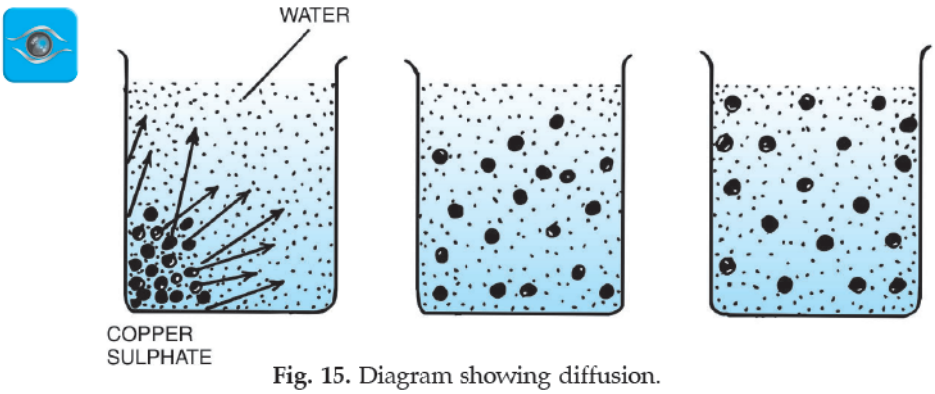


Fig. 15. Diagram showing diffusion.

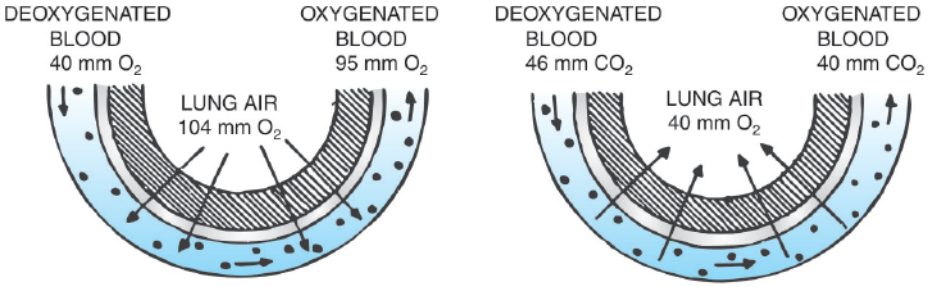


Fig. 16. Pulmonary gas exchange.

Practical demonstration of osmosis

Tonicity (Gr. *tonos* = stress). Tonicity is the **tension or stress developed in a system due to presence of osmotically active substances in it.** On the basis of tonicity, solutions are of **three types :**

(i) Isotonic solution. It is that solution which has same osmotic pressure (or concentration) as that of cytoplasm so osmosis occurs equally in both directions *e.g.* **0.9% sodium chloride** solution and **5% glucose** solution **(Fig. 17A)**. Drugs are injected into the blood in isotonic solutions.

(ii) Hypertonic solution. It is that solution whose concentration or osmotic pressure is higher than that of cytoplasm, so there is osmotic outflow of water from the cell, called **exosmosis** *e.g.* **2% sodium chloride** solution. **or 10% Glucose solution.** When RBCs are placed in a hypertonic solution, RBCs become smaller and crenated **(Fig. 17B)**.

(iii) Hypotonic solution. It is that solution whose concentration or osmotic pressure is less than that of cytoplasm, so there is osmotic inflow of water into the cell, called **endosmosis** *e.g.* when RBCs are placed in a hypotonic solution **(0.5% NaCl)**, then RBCs become swollen and spherical **(Fig. 17C)**.

So there are two forms of osmosis : **endosmosis** and **exosmosis.**

When RBCs are placed in distilled water, then concentration difference is so high and endosmosis is so fast that RBCs burst due to turgor pressure which cannot be resisted by cell membrane.

Significance of osmosis

(i) It helps in **absorption of water** from the soil by root hair.

(ii) It helps in **developing turgor pressure** which helps in opening and closing of stomata and movements of leaflets in *Mimosa pudica* (touch-me-not).

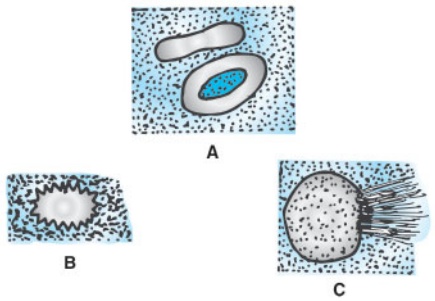


Fig. 17. Effect of **A.** Isotonic; **B.** Hypertonic and **C.** Hypotonic solutions on RBCs.

(iii) It helps in **cell to cell movement of water**.

(iv) It maintains **turgidity of cells** which helps in deeper penetration of roots, extension of leaves, stretching of stem, etc.

(v) It helps in growth of radicle and plumule during **seed germination.**

3. Plasmolysis and Deplasmolysis (Fig. 18)

When a living plant cell is placed in a hypertonic solution, then exosmosis occurs from the central vacuole. The protoplasm starts separating from the cell wall, called **incipient plasmolysis.** If the process continues, then finally the protoplasm is completely separated from the cell wall, called **evident plasmolysis. This phenomenon when a fully turgid (swollen protoplasm) cell changes into flaccid (shrunken cytoplasm) cell, is called plasmolysis** and the cell is called **plasmolysed.**

When a plasmolysed cell is placed in a hypotonic solution, then endosmosis occurs. The protoplasm increases in size and finally comes in contact with the cell wall to regain original turgid condition. **This phenomenon when a flaccid or plasmolysed cell changes into a cell with turgid condition, is called deplasmolysis** and the cell is called **deplasmolysed.**

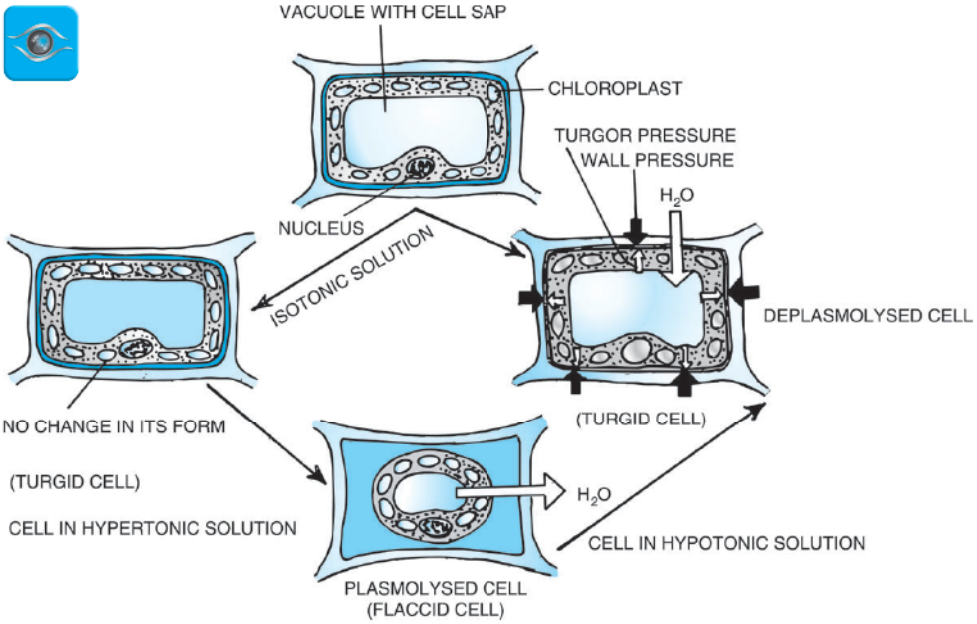


Fig. 18. Effect of Isotonic, Hypotonic and Hypertonic solutions on a plant cell.

Table 6. Differences between Diffusion and Osmosis.

Characters	Diffusion	Osmosis
1. Direction of flow	From higher concentration (or higher free energy) to lower concentration (or lower free energy).	From lower concentration to higher concentration.
2. Nature of molecules	May be solid or liquid or gas.	Always water or any other solvent molecules.
3. Nature of medium	In any medium.	Always in liquid medium.
4. Semipermeable membrane	May or may not be required.	Always required.
5. Force	Diffusion pressure.	Osmotic pressure.

Significance of Plasmolysis

(i) It is practised to know **living nature of cell.**

(ii) It is used to kill the weeds and earthworms in lawn tennis courts by **salting**.

(iii) It is used to **preserve meat, jelly etc.** as their salting kills bacteria and spores of fungi by plasmolysis.

(iv) It is used to determine the **osmotic pressure.**

II. ACTIVE PROCESSES

These are characterised by :

(a) Materials move **against the concentration gradient.**

(b) These are **energy dependent processes** so are **rapid** processes.

(c) Materials **can be transported completely.**

(d) These are **highly affected** by low temperature, absence of oxygen and presence of cyanides (**metabolic inhibitors**).

(e) These occur through a **semipermeable membrane.**

(f) Movement of molecules or ions is **unidi-rectional.**

(g) These are **selective processes** so always involve **carrier molecules.**

The active processes involve : **active transport, endocytosis** and **exocytosis.**

1. Active Transport

Definition. It is energy-dependent transport of microbiomolecules or ions across a semipermeable membrane against the concentration (or electrochemical) gradient.

Proof of Active Transport. (Na^+/K^+ Exchange Pump — Fig. 19). A resting or unexcited cell-membrane is electropositive on outer side and electronegative on inner side (due to more organic anions inside). Regarding the ionic distribution, ECF is with more Na^+ (10 times) while intracellular cytoplasm is with more K^+ (30 to 40 times) and organic anions. At rest, the membrane is more permeable to K^+ than Na^+. When a cell-membrane is stimulated, it becomes **depolarized** due to rapid diffusion of Na^+ from ECF into the cytoplasm on the basis of electrochemical gradient called **Na^+ influx.** It becomes electronegative on outside and electropositive on inside. After maximum depolarization, the cell-membrane becomes more permeable to K^+ which diffuses from inside to outside the cell (called **K^+ eflux**) due to which the cell-membrane again becomes electropositive on outside and electronegative on inside. This is called **repolarization.**

Original ionic distribution is maintained by **Na^+/K^+ exchange pump** present in the plasma-membrane which actively moves Na^+ from inside to outside and K^+ from outside to inside. Cell membrane again becomes **polarized.** In this, the pump is formed of **carrier protein molecule (Sodium-potassium ATPase)** which accepts sodium and ATP on inner side and accepts potassium on its outer side. For each molecule of ATP used, three Na^+ ions are pumped out and two K^+ ions are pumped in. So there is far higher Na^+ concentration outside the cell than inside.

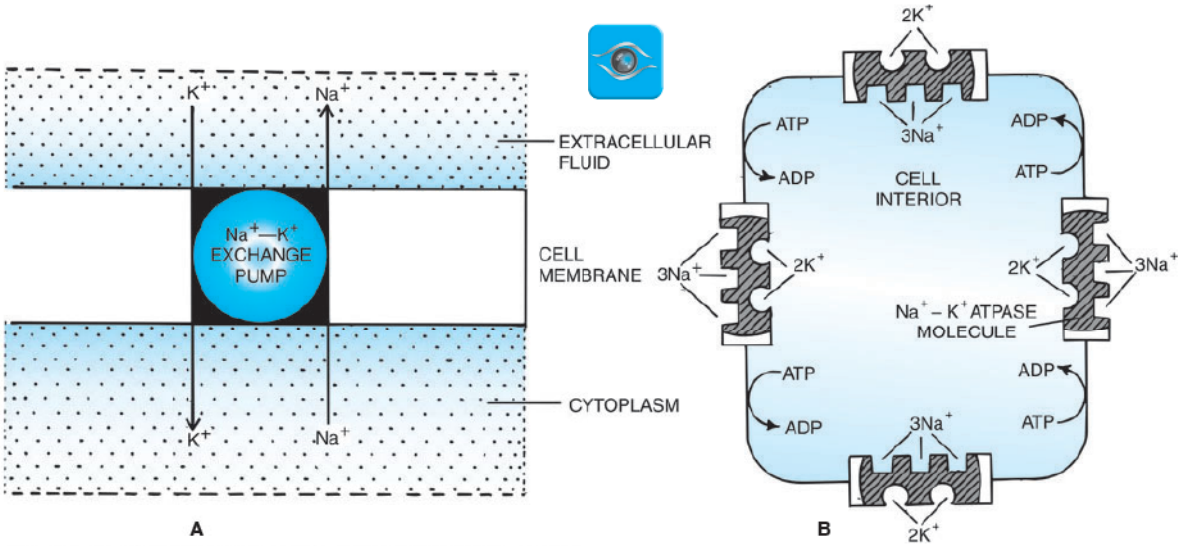


Fig. 19. **A.** Sodium-Potassium exchange pump. **B.** Diagrammatic illustration of sodium-potassium pump.

Significance of Active Transport

(a) It helps in controlling **osmoregulation.**

(b) It helps in **muscle-contraction** and **nerve-impulse conduction.**

(c) It also helps in **intestinal absorption of sugars and amino acids.**

(d) It helps in maintaining **high intracellular K^+ concentration** which in turn helps in many other vital metabolic activities.

(e) Many sea birds like **seagulls** and **penguins** expel excess of salts (especially NaCl) by active transport through their nasal salt glands.

(f) Helps in **enterohepatic circulation of bile salts.**

(g) Selective reabsorption of useful materials like glucose, amino acids and Na^+ from the nephric filtrate.

2. Endocytosis and Exocytosis

(a) Endocytosis (Gr. *endon*=within; *kytos*=cell). **It is the process by which large sized liquid or solid materials are taken inside the cell through plasma membrane.** It is again of **two types:**

(i) Pinocytosis (Gr. *pinein* = to drink, **—Fig. 20A**), also called **cell-drinking, is the process which involves intake of large sized liquid nutrients,** while the cell showing pinocytosis, is called **pinocyte.** In this, the extracellular solutes such as insulin and lipoproteins are taken into a pocket formed by invagination of plasma membrane and called **pinocytotic vesicle.** It later separates from the cell-membrane as an intracellular food vacuole, called **pinosome.** Pinosome is digested by the hydrolytic enzymes of primary lysosome *e.g.* Intestinal epithelial cells take micelle by pinocytosis.

(ii) Phagocytosis (Gr. *phagein* = to eat, **— Fig. 20B**), also called **cell-eating, is the process which involves the intake of large sized solid particles including cellular-debris and microbes.** It was first observed by **Metchnikoff** (1883 A.D.). In this, the material to be ingested first binds to the cell surface which invaginates to form a **phagocytotic vesicle.** It later separates from cell membrane as an intracellular food vacuole, called **phagosome.** Phagosome is digested by the hydrolytic enzymes of primary lysosome. Cells involved in phagocytosis are called **phagocytes** *e.g.* **WBCs** and **macrophages** remove damaged cells, viruses, bacteria and dust particles.

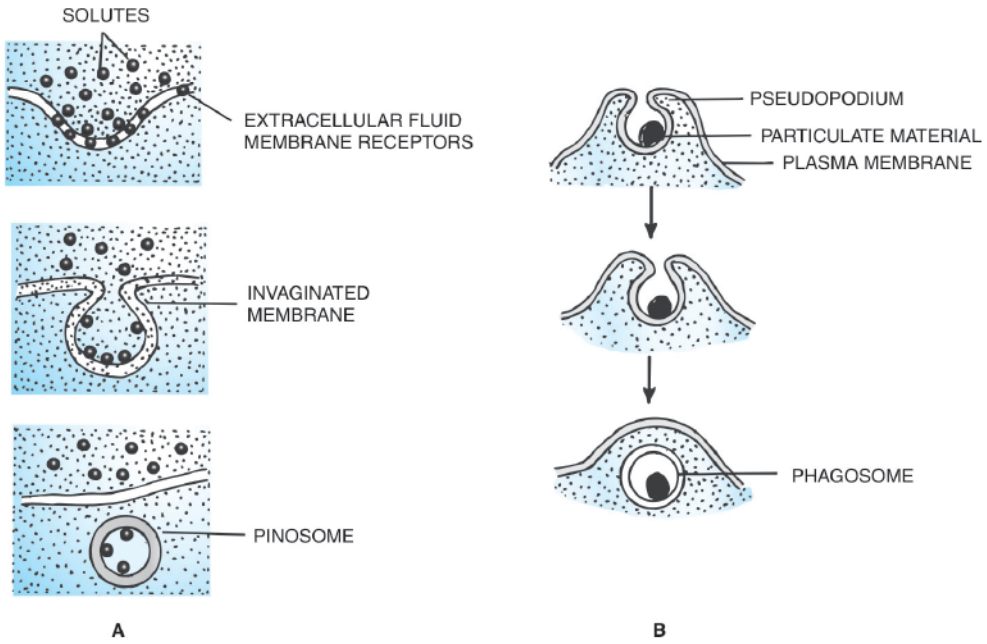


Fig. 20. A. Pinocytosis. **B.** Phagocytosis.

Table 7. Differences between Pinocytosis and Phagocytosis.

Characters	Pinocytosis	Phagocytosis
1. Nature of material	Intake of **fluid material.**	Intake of **solid material.**
2. Exocytosis	Not involved.	Undigested solid food is expelled out by exocytosis.
3. Size of vesicle	Pinocytotic vesicle is about 0.1μ sized.	Phagocytotic vesicle is about 1 to 2μ sized.
4. Microfilaments	No role.	Help in formation of phagocytotic vesicle.
5. Function	Nutritive.	Nutritive and defensive.
6. Occurrence	**Erythroblasts** of bone-marrow.	Amoeboid protozoans, WBCs and Macrophages.

Table 8. Differences between Passive transport and Active transport.

Characters	Passive transport	Active transport
1. Direction of Transport	From higher concentration to lower concentration.	From lower concentration to higher concentration.
2. Energy	Not dependent upon energy.	Depends upon energy supplied by ATP.
3. Direction	Bi-directional.	Unidirectional.
4. Nature of process	Physical and non-selective process.	Vital and selective process.
5. Speed	Slow process.	Rapid process.
6. Effect of temperature, oxygen and cyanides	Not affected by absence of oxygen and presence of cyanides.	Rate is decreased in the absence of oxygen and presence of cyanides.
7. Carrier proteins	Not dependent.	Dependent.

(iii) Exocytosis (Gr. *exo* = outside). It is also called **emeiocytosis or cell-vomiting or ephagy. It is expelling of large sized materials outside cell through cell-membrane (Fig. 21).**

In this, the materials, to be expelled outside the cell, are accumulated in **exocytotic vesicle** which moves outwards, fuses with plasma-membrane and the contents are discharged outside the cell *e.g.*

(a) Release of secretions of glandular cells of liver, pancreas etc.

(b) Expelling of residual body.

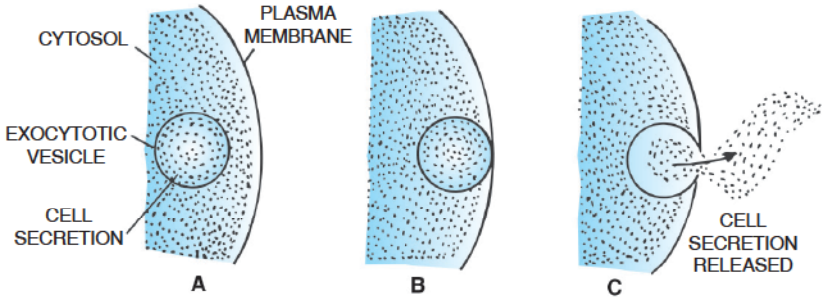


Fig. 21. Exocytosis.

Table 9. Processes involved in Transport of Materials Across Biomembranes.

Transport Mechanisms

Passive processes

Diffusion (Along concentration gradient *e.g.* Pulmonary gas exchange).

Osmosis (Passive movement of water or any other solvent *e.g.* selective reabsorption of water and urea from nephric filtrate; plasmolysis in plant cell).

Passive transport (Materials moving through channel in carrier proteins along concentration gradient *e.g.* inward movement of Na^+ during depolarization of nerve fibre or muscle fibre).

Facilitated diffusion (Along concentration gradient but assisted by carrier proteins *e.g.* absorption of fructose and entry of glucose in RBCs).

Active processes

Active transport
Energy dependent movement of materials against concentration gradient assisted by carriers or permeases *e.g.* reabsorption of glucose and amino acids from nephric filtrate.

Endocytosis
Intaking of materials by a cell through cell membrane and is energy dependent

Exocytosis
Expelling of materials out of cell through cell membrane *e.g.* release of secretions from gland cells, release of neurotransmitter from nerve cells, etc.

Pinocytosis
Intaking of large sized liquid nutrients *e.g.* Intaking of iron by bone marrow and intaking of micelle by intestinal cells.

Phagocytosis
Intaking of large sized solid particles *e.g.* engulfing of microbes by phagocytes; ingestion in *Amoeba*.

PRACTICE PROBLEMS – PLASMA MEMBRANE

27. What is chemical nature of plasma membrane?
28. Why are phospholipid molecules called amphipathic molecule?
29. Who coined the term unit membrane?
30. Who proposed Fluid-mosaic model of plasma membrane?
31. State the fluid mosaic model in one line?
32. Why is plasma membrane called quasi-fluid membrane?
33. Which two types of proteins are present in plasma membrane?
34. Why is plasma membrane called selectively permeable membrane?
35. Name two types of processes involved in transport of materials across the plasma membrane.
36. Why is plasma membrane called a dynamic membrane?
37. Name various physical processes involved in transport of materials.
38. Name various active processes involved in transport of materials.
39. Define diffusion. Give one example of it in a living system.
40. What is osmosis.? Name one experiment by which it can be demonstrated.
41. How does facilitated diffusion differ from simple diffusion?
42. Give one major difference between active processes and passive processes.
43. What is endocytosis? Name two processes of endocytosis.
44. Give one major difference between pinocytosis and phagocytosis.
45. Define exocytosis. Give one example of it.

ANSWERS TO PRACTICE PROBLEMS

27. Lipoproteinous and trilaminar.
28. These have both hydrophilic and hydrophobic groups.
29. J. David Robertson.
30. Singer and Nicolson (1972).
31. "Protein -icebergs in a sea of lipids."
32. Phospholipid-bilayer is fluidy in nature in which protein biomolecules also change their position.
33. Extrinsic proteins and Intrinsic proteins.
34. It allows only selected materials to pass through to selective extent.
35. Active processes and passive processes.
36. A number of transport mechanisms are involved in the transport of materials across the plasma membrane.
37. Diffusion, osmosis, dialysis and facilitated diffusion.
38. Active transport, pinocytosis, phagocytosis and exocytosis.
39. It is transport of materials from higher concentration to lower concentration due to intrinsic kinetic energy of the molecules e.g. exchange of O_2 of air and CO_2 of blood at the lung alveoli.
40. It is transport of water or any other solvent from lower concentration to higher concentration through a semipermeable membrane without the expenditure of energy. Osmosis can be demonstrated by potato osmoscope.
41. Facilitated diffusion occurs in the presence of carrier molecules so is faster than simple diffusion.
42. Active processes include transport of materials in the presence of energy while passive processes include transport of materials in the absence of energy.
43. It is inward movement of macrobiomolecules inside the cell through PM in the presence of energy. Two processes are : **Pinocytosis** and **Phagocytosis.**
44. Pinocytosis involves intaking liquid nutrients while phagocytosis involves engulfing of solid nutrients.
45. It is outward movement of cellular secretions or wastes outside the cell through PM e.g. expelling of residual bodies.

REMEMBER

- Brownian movements were first reported by **Robert Brown (1827)**.
- Depolarization of muscle fibre and nerve fibre occurs by inward diffusion of Na^+ ions.
- Osmosis can be experimentally demonstrated by **Thistle funnel experiment, Plasmolysis** and **Potato osmoscope.**
- **Dialysis :** A type of passive transport in which lipid-soluble dissolved substances move through the PM along the concentration gradient.
- **Ligands :** These are specific extracellular molecules which bind with specific protein receptors on the PM during receptor- mediated endocytosis.
- **Endocytotic cycle. :** Process of recycling of cell membrane in which loss of a part of cell membrane by endocytosis is compensated by gain of a part of cell membrane by exocytosis.

II. CELL WALL

1. Definition. Cell wall is the outermost, rigid, protective and supportive layer found in all the plant cells, bacteria, cyanobacteria and some protists. It is not found in animal cells.

2. Discovery. By **Robert Hooke** (1665 A.D.).

3. Thickness. Varies from 0.1 µm to 10 µm.

4. Structure (Fig. 22). Structurally, the plant cell wall is formed of **two coats :**

(a) Primary cell wall. It is outer, thinner (1-3 µm), elastic and living coat present in the **meristematic (dividing) and parenchymal cells.** It is chemically formed of cellulose, hemicellulose, pectins and proteins.

(b) Secondary cell wall. It lies inner to primary cell wall only in **mature and non-dividing cells** (e.g. tracheids, vessels, collenchymal and sclerenchymal cells). It is thicker (5-10 µm) and is formed of three layers called S_1, S_2 and S_3 in which the macrofibrils are oriented in different directions. It is chemically formed of cellulose, hemicellulose and is further deposited with water-proof **suberin** in cork cells or **cutin** on all the aerial parts of plants or **lignin** e.g., woody plants or **silica** in grasses. Lignin gives strength and rigidity while suberin and cutin cause water-proofing of cell wall.

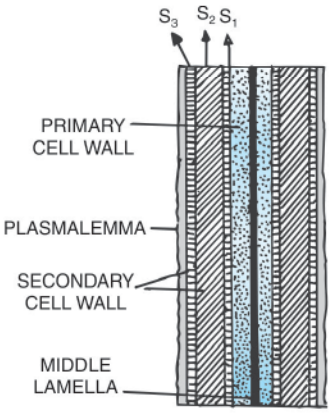


Fig. 22. Structure of cell wall.

Middle lamella. It is a thin **binding layer** between the cell wall of adjacent plant cells and is the joint secretion of both the cells. It is chemically formed of **pectates of calcium and magnesium.** It is absent on out free surface.

5. Plasmodesmata. (Fig. 23). These are **cytoplasmic strands** which act as **intercellular junctions** between the adjacent plant cells and pass through symplastic areas where secondary cell wall is absent. Each is formed of a simple or branched **desmotubule** connecting with endoplasmic reticulum of the adjoining cells. These help in **exchange of materials** between the cells.

6. Cell-wall in other organisms :

(a) In fungi. In most of the members of fungi, the cell wall is formed of **chitin (fungal cellulose)** but in members of class **Phycomycetes** (e.g., *Saprolagnia* etc.), the cell wall is formed of cellulose.

(b) In prokaryotes. It is mainly formed of **peptidoglycan** except **mycoplasma** (PPLO) in which cell wall is absent.

(c) In algae. Cell wall is formed of cellulose, galactans, mannans and minerals (e.g., $CaCO_3$).

7. Chemical composition. Chemically, the plant cell wall is formed of :

Cellulose	=	10-15% (In the form of fibrils).
Hemicellulose	=	5-10%
Water	=	60%
Pectic substances	=	2-8%
Proteins	=	1-2%
Lipids	=	0.5-3%

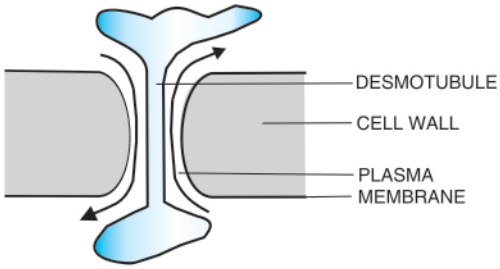


Fig. 23. Plasmodesmata.

Table 10. Differences between Primary and Secondary cell wall.

Characters	Primary cell wall	Secondary cell wall
1. Occurrence	In all the plant cells.	In only mature and non-dividing cells.
2. Position	Inner to middle lamella.	Inner to primary cell wall.
3. Nature	Elastic and thinner (1-3 µm)	Inelastic, rigid and thicker (5-10 µm).
4. Nature of growth	Intussusceptional.	Accretional.
5. Pits	Absent.	Present.
6. Additional materials	Absent.	Present—lignin, suberin or cutin.
7. Amount of cellulose	Low.	High.
8. Extensibility	Present.	Generally absent.
9. Arrangement of fibrils	Wavy and loosely arranged.	Closely, straight and parallel arranged.
10. Hydration.	More (60%).	Less (30-40%).

8. Origin of cell wall (Fig. 24). New cell wall is formed **during cytokinesis** of plant cell division by **cell plate formation.** A number of elements, called **phragmoplasts,** line up at equator and fuse to form a cell plate which finally grows on both sides and forms middle lamella. The middle lamella is deposited with cellulose etc. to form cell wall.

9. Functions

(a) It provides **protection** to inner contents from mechanical injuries and entry of germs.

(b) It provides **mechanical support.**

(c) It maintains **shape** of the cells.

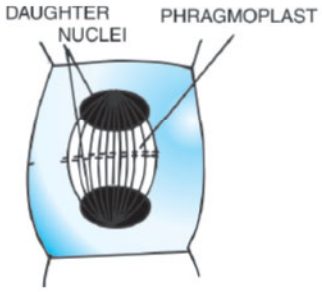


Fig. 24. Origin of cell wall.

(d) Cell wall of root hair helps in **absorption of water and minerals** from the soil.

(e) Suberin and cutin **prevent evaporation of water.**

(f) It **prevents undue expansion** of the cell.

(g) It is involved in **many enzymatic activities.**

(h) Helps in **cellular interactions** and barrier to undesirable macromolecules.

(i) It exerts inward **wall pressure** to resist turgor pressure so as to prevent bursting of cell.

III. CELL-COAT (GLYCOCALYX)

1. Position. It is present outside the plasma-membrane in many protistans and animal cells.

2. Structure. It is a filamentous layer of oligosaccharides.

3. Functions

(a) It **protects** the plasma membrane.

(b) It helps in **recognition of cells** and allow histocompatible cells to **form the tissues.**

(c) It provides **shape** to the cell.

(d) It helps in **recognition of microbes** for defence.

(e) It plays important role in **blood-grouping, cancer** and **rejection** of transplanted organs.

PRACTICE PROBLEMS—CELL WALL AND CELL COAT

46. Give the occurrence of cell wall.

47. List one major difference between primary wall and secondary cell wall.

48. What is suberinization? Give its significance.

49. What is middle lamella?

50. Give the period of formation of new cell wall.

51. Name two major chemical compounds present in the cell wall.

ANSWERS TO PRACTICE PROBLEMS

46. Outer coat of plants, cyanobacteria, some protists, fungi, etc.

47. Primary cell wall is formed of cellulose and hemicellulose, while secondary cell wall is also deposited with cutin, suberin and lignin.

48. Deposition of suberin in the secondary call wall. Suberin makes the cells water proof.

49. It is a binding layer between the adjacent cell walls.

50. During cytokinesis of cell division of plant cell.

51. Water = 60%; cellulose = 10–15%; Hemicellulose = 5–10%

IV. CYTOPLASM

1. Position and structure. It is an amorphous, translucent, homogeneous colloidal ground substance lying between the plasma membrane and the nucleus. It is differentiated into two parts :

(a) Cytoplasmic matrix,

(b) Cytoplasmic structures.

(a) Cytoplasmic matrix, also called **hyaloplasm** or **cytosol** is again differentiated into two parts : **Ectoplasm** or **cortex** is peripheral, denser and non-granular (represents **gel** state), and **endoplasm** or **medulla** is inner, less-denser and granular part (represent **sol** state). The hyaloplasm behaves as a **reversible sol-gel colloid system**. Chemically, the cytoplasmic matrix is formed of true solution containing nucleotides, vitamins, t-RNAs, many minerals, sugars, amino acids and colloidal solutions of proteins. Fats usually occur in emulsion form.

2. Functions

(a) It provides **raw materials** to cell-organelles.

(b) It helps in **exchange of materials** between various cell-organelles and also with ECF.

(c) It is the **seat of biosynthesis.**

(d) It is the seat of many **catabolic pathwa**

(b) Cytoplasmic structures. These lie in the cytoplasm and are of **two types : Cell organelles** and **cell inclusions.**

LEARNING PLUS

CYCLOSIS

Another peculiar feature of eukaryotic cellular-cytoplasm is **cyclosis** which is the streaming movement of cytoplasm. Cyclosis is of two types : **rotational** or **uni-directional type** (cytoplasmic movements in one direction only around the central vacuole e.g., in young cells of *Hydrilla*, *Chara* or *Vallisneria* leaf) and **circulational** or **multi-directional type** (cytoplasmic movements in different directions around different vacuoles in the same cell *e.g.*, in the cells of staminal hair of *Rhoea* or *Tradescantia*). It helps in :

1. **Formation of pseudopodia** in leucocytes.
2. **Movement** of cellular organelles and inclusions.
3. **Distribution** of materials inside the cell.

NOTE

- **Desmotubules :** SER tubules which help in the formation of plasmodesmata.
- **Symplasm :** Areas of cytoplasmic continuity between adjacent cells e.g. plasmodesmata.
- **Apoplasm :** Intercellular spaces with non-living matter.

ADDITIONAL USEFUL INFORMATIONS ABOUT CELL WALL, HYALOPLASM AND CYCLOSIS FOR COMPETITIVE EXAMINATIONS

- *Primary cell wall is a living coat and shows **intussusceptional growth**, while secondary cell wall shows **accretional growth**.*
- *Cell wall is absent in gametes and zoospores of plants, and also absent in animal cells.*
- ***Suberinization** : Deposition of secondary cell wall of cork cells with a water-proof fatty material, **suberin**.*
- ***Cutinisation** : Deposition of secondary cell wall of cells of aerial parts of plants with a fatty material, **cutin**, to reduce transpiration.*
- ***Lignification** : Deposition of secondary cell wall of cells of woody plants with **lignin** (a polymer of coniferyl and coumaryl alcohol).*
- ***Middle lamella** is joint secretion of both the cells during cytokinesis.*
- *Ripe fruits become soft due to partial dissolution of pectic substances of middle lamella.*
- ***Silica** is deposited in cell wall of cells of grasses and diatoms.*
- ***Hyaloplasm** is a crystallo-colloidal system (Kolliker, 1862).*
- ***Thixotropism** (Gr. thixis = touch; trope = to change) : Hyaloplasm behaving as **reversible sol-gel colloid system**.*
- *Fruit ripening is due to an enzyme, **polygalactouronase**.*
- ***Mesokaryotic cells** : Found in **Dinoflagellates**. Chromosomes are condensed even in interphase. Cell division occurs by **dinomitosis**.*

CELL ORGANELLES

These are **living sub-cellular structures** of the cytoplasm and are also called **protoplasmic bodies** or **organoids.** There are many types of membrane–bounded cell organelles which collectively form **endomembrane system** because their functions are coordinated. This system includes ER, Golgi apparatus, lysosomes, peroxisomes and vacuoles. Because the functions of mitochondria and chloroplasts are not coordinated with these components so these are not included in endomembrane system. Every cell organelle has characteristic morphology, distinct chemical composition and definite function. Cell-organelles include :

A. ENDOPLASMIC RETICULUM (ER)

1. Discovery. Though ER was first observed by **Garnier** (1897 A.D.) but its ultrastructure was first given by **Porter, Claude** and **Fullam** (1945 A.D.). Term **'Endoplasmic Reticulum'** was given by **Porter.**

2. Definition. It is a well-developed electron microscopic network of interconnected cisternae, tubules and vesicles present throughout the cytoplasm, especially in the endoplasm.

3. Occurrence. It is absent from the prokaryotes but is present in all the eukaryotes except germinal cells and mature mammalian erythrocytes.

4. Types of ER. On the basis of presence or absence of ribosomes, ER is of **two types** (Table 11) :

Smooth or Agranular Endoplasmic Reticulum (SER), and Rough or Granular Endoplasmic Reticulum (RER).

5. Ultrastructure (Fig. 25). ER is formed of three types of elements :

(a) Cisternae. These are narrow, two -layered and unbranched elements present near the nucleus. These lie one upon the other and are interconnected. Each is about **40-50 µm** in diameter and studded with ribosomes. These are more in protein forming cells.

(b) Vesicles. These are oval or rounded and are scattered in cytoplasm. Size ranges from **25-500 µm.** These are studded with ribosomes and are more in protein forming cells.

(c) Tubules. These are wider, tubular but branched elements mainly present near the cell membrane. These are without ribosomes. Each is about **50-100 µm** in diameter. These are more in lipid forming cells.

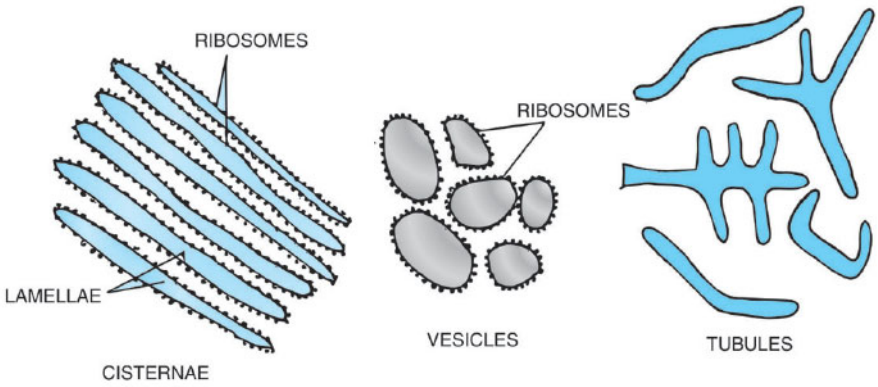


Fig. 25. Elements of Endoplasmic Reticulum.

Table 11. Differences between SER and RER.

Characters	SER	RER
1. Ribosomes	Absent.	Present and is also called **∝-cytomembrane.**
2. Position	Mainly present near the cell-membrane.	Mainly present near the nucleus.
3. Component	Mainly formed of **tubules.**	Mainly formed of **cisternae.**
4. Occurrence	Mainly found in lipid forming cells e.g., **adipocytes** (fat cells), **interstitial cells** (of testis), **adrenal cortical cells, glycogen-storing cells of liver, muscle, leucocytes** etc.	Mainly found in protein forming cells e.g., **pancreatic acinal cells, goblet cells, plasma cells** (produce antibodies), **Nissl's granules** of cells, nerve cells etc.
5. Functions	Biosynthesis of fats, steroid hormones, glycogenolysis, detoxification, etc.	Biosynthesis of proteins, transition vesicles, nuclear envelope, etc.

6. Functions

(a) Common Functions of SER and RER

(*i*) ER acts as a part of **cell-circulatory system** and helps in transportation of materials in a **directional flow.**

(*ii*) ER acts as **cytoskeleton** and provides **mechanical support** and **shape** to the cell.

(*iii*) ER acts as a part of **segregation-apparatus** and divides the cytoplasm into **luminal** (inside ER) and **extra-luminal** (outside ER) **chambers** and regulates the exchange of materials between them. **Compartmentalisation is essential for cellular life.**

(*iv*) ER helps in the **formation of primary lysosome.**

(*v*) **Synthesis of nuclear-envelope** during telophase.

(*vi*) It participates in the **formation of cell-plate.**

(*vii*) ER has about 30 types of enzymes which help in **biosynthesis.**

(*viii*) ER helps in **transfer of genetic information** from nucleus to various cell organelles.

(*ix*) **Storage** of synthetic products like glycogen.

(*x*) ER forms tubular extensions called **desmotubules** which connect the ER of adjoining cells.

(b) Special Functions of RER

(*i*) RER increases (5-6 times) the rate of **protein synthesis.**

(*ii*) RER **forms SER** by the loss of ribosomes.

(*iii*) RER forms the **transition vesicles** which carry the materials to the cisternae of Golgi apparatus.

(*iv*) Reformation of nuclear membrane during telophase of cell division.

(c) Special Functions of SER

(*i*) SER is involved in the **lipid synthesis** e.g., of triglycerides in adipocytes.

(*ii*) **Synthesis of steroid hormones** e.g., sex hormones like **testosterone** of testis and **estrogens** of ovary.

(*iii*) It helps in **glycogenolysis** in the liver cells.

(*iv*) SER helps in **detoxification** of harmful drugs like **phenobarbitol** and carcinogen like **3-methyl cholantrene** and **3, 4-Benzpyrene.**

(*v*) **Sarcoplasmic reticulum** helps in **muscle contraction.**

B. GOLGI BODY

1. Discovery. Golgi body, also called **Lipochondria** or **Idiosome** or **Dalton complex** or **Golgi complex** or **Golgi apparatus,** though was first observed by **George** (1867 A.D.) but its morphological details were given by **Camilo Golgi** (1898 A.D.) in the nerve cells of cats and barn owls. It is a light microscopic organelle.

2. Occurrence. Golgi body is absent from the prokaryotes. It is present in all the eukaryotes except mature mammalian RBCs, antherozooids of Bryophytes and Pteridophytes and sieve tube cells of Angiosperms.

3. Position. In the vertebrate cells, Golgi body is single (called **Golgisome**) and **localized**. It lies around or above centrioles near the nucleus, while a number of Golgi bodies are **perinuclear** in the nerve cells. In the invertebrate and plant cells, a number of Golgi bodies are scattered irregularly in the cytoplasm and are called **dictyosomes.** This condition is called **diffused.**

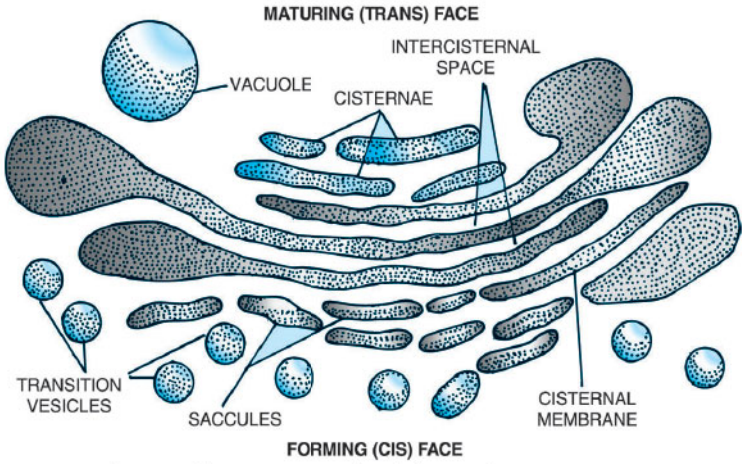


Fig. 26. Ultrastructure of Golgi complex.

are scattered irregularly in the cytoplasm and are called **dictyosomes.** This condition is called **diffused.**

4. Size. It is large sized in mature, functional and secretory cells e.g., nerve cells, pancreatic cells, liver cells, goblet cells, germinal cells etc. but is small sized in non-secretory cells e.g. muscle cells.

5. Structure (Fig. 26). Under electron microscope, (by **Dalton and Felix,** 1954) the Golgi body is formed of **three types of elements :**

(a) Cisternae (also called **flattened sacs** or **saccules** or **parallel membranes**). These are 4 to 8 elongated double layered, flat and curved components with swollen ends present one upon the other. Each cisterna is 0.5– 1.0 µm in diameter. Swollen ends of cisternae are called **Golgian vacuoles.** In fungi, a dictyosome is **unicisternal.**

(b) Vacuoles. These are spherical components and lie towards the concave side of the cisternae.

(c) Vesicles. These are small sized components present along the convex surface or edges of the cisternae.

These may be **smooth** (contain cellular secretions) or **coated** with rough surface.

The Golgi body has a **definite polarity**. Its concave side is always directed towards the cell membrane and is called **maturation face (trans-face)** while its convex surface is towards the nucleus and is called **formative face (cis-face).**

9. Functions :

(a) It is involved in **cell secretion,** so is large sized in secretory cells.

(b) It acts as **packaging membrane** and condenses the materials in the **secretory vesicles.**

(c) It takes part in **cell plate formation.**

(d) It helps in **synthesis of pectic substances.**

(e) Burgos and Fawcett reported the formation of **acrosome** of sperm from Golgi body.

(f) It helps in the **formation of primary lysosome**.

(g) It takes part in **vitellogenesis** (Yolk-synthesis).

(h) Biosynthesis of glycoproteins and **glycolipids** by **glycosylation**.

(j) It is a component of **intracellular transport system** so called **director of Macromolecular traffic.**

(k) Transformation and recycling of plasma membrane.

C. LYSOSOMES

1. Discovery. These were first discovered by a Belgian biochemist, **Christian de Duve** (1955 A.D.) in the liver cells.

2. Definition. Lysosomes are electron microscopic, vesicular structures of the cytoplasm which are involved in intra-cellular digestive activities, so called lysosomes.

3. Occurrence. These are absent from the prokaryotes but are present in all the eukaryotic animal cells (except mammalian RBCs), some fungi (e.g., Yeasts, *Neurospora*), some protists (e.g., *Euglena*) and meristematic cells (e.g., root tip cells of maize).

COMPETITION PLUS

On the basis of **nature of matrix,** lysosomes are of **four types**, so show **polymorphism (Fig. 27)** :

(*i*) **Primary lysosomes.** These have digestive enzymes in inactive form and are also called **storage granules.**

(*ii*) **Secondary lysosomes** (also called **digestive vacuoles or heterophagosomes**). These have digestive enzymes and ingested food. It is formed by fusion of primary lysosomes and endosome.

(*iii*) **Autophagosomes.** These are formed by fusion of primary lysosome and reserve food or some cell-organelles like mitochondria, fragments of ER etc. during deficiency of food.

(*iv*) **Residual body** or **Tertiary lysosome** or **Telolysosome.** It is the lysosome with only undigested food. It is normally expelled out of the cell by exocytosis.

So the lysosomes are found in four forms and are called **polymorphic organelle.**

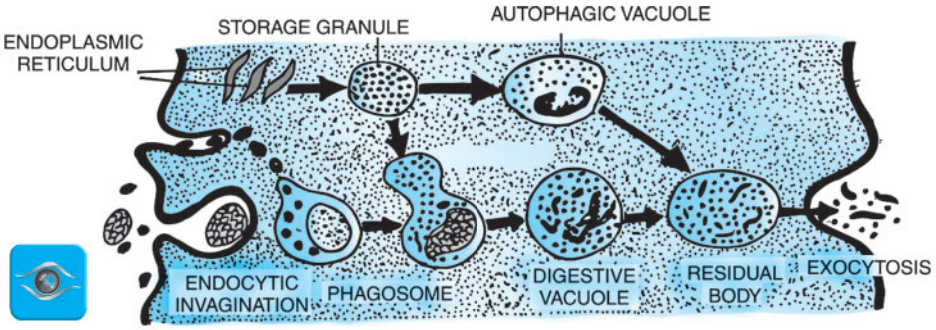


Fig. 27. Polymorphism in Lysosome.

4. Shape. These are generally **spherical** in shape.

5. Size. Size range is 0.2-0.8 µm. (Average 0.5 µm).

6. Number. Lysosomes are more in those cells which are involved in intracellular digestive activities e.g., **WBCs** of blood; **histiocytes** of connective tissue; **phagocytes; osteoclasts;** etc.

7. Ultrastructure. Under electron microscope, a lysosome is formed of **two parts :**

(a) Limiting membrane. It is outer, and **single layered.** It keeps a limit on digestive enzymes.

(b) Matrix. It is inner, finely granular and **highly heterogeneous** ground substance inside the membrane.

8. Chemical composition. Matrix of primary lysosome is formed of **hydrolases** which operate in acidic medium (pH 5.0), so called **acidic hydrolases.** Lysosomal enzymes are divided in **six categories :**

(a) Proteases e.g., cathepsin and collagenase.

(b) Nucleases e.g., DNAse and RNAse.

(c) Glycosidases e.g., β-galactosidase, β-glucoronidase.

(d) Phosphatases e.g., ATPase, acid phosphatase.

(e) Sulphatases e.g., for sulphate-linked organic compounds

(f) Esterases e.g., phospholipase, acid lipase.

9. Origin. Lysosomes are formed from cisternae of Golgi body.

10. Functions. Primary function is **intracellular digestion** of all the categories of macromolecules.

(a) Heterophagy. It involves the **digestion of exogenous materials** of high molecular weight inside the cell. It is found in protozoans, sponges and coelenterates. It is a **defensive mechanism** against invading microbes. So are also called "**disposal units**". It helps in **physiological rejuvenation.**

(b) Autophagy. It involves the **digestion of reserve food of cell or some cell organelles** like fragments of ER, mitochondria etc. by lysosomal enzymes in autophagosomes during starvation.

(c) Autolysis. It involves **self-digestion** of cell by lysosomal enzymes when, after the cell death, lysosomal enzymes are released. So the lysosomes are also called **suicidal bags** or **atom bombs** e.g., lysosomal enzymes cause dissolution of tail of tadpole larva during metamorphosis. So the lysosomes are also called **recycling centres.**

(d) Extracellular digestion. In this, primary lysosome releases its enzymes by exocytosis to digest food outside e.g., **acrosome** releases **hyaluronidase (lytic enzyme)** to digest egg envelope locally for sperm entry.

(e) Lysosomes initiate **cell-division** by digesting repressor molecules.

(f) DNAse of lysosome may cause **gene mutations** which may cause disease like **leukemia** (blood cancer).

(g) Neutrophils (WBC-type) of blood, called **soldiers** of body, engulf and digest the microbes. So these provide **natural defence** against the microbes.

(h) Monocytes (WBC-type) of blood, called **natural scavengers**, engulf and digest the dead cells of the body.

(i) Sometimes residual bodies accumulate inside the cells leading to **storage diseases** e.g., a glycogen storage disease called **Pompe's disease** (due to deficiency of acid alpha glucosidase enzyme), hepatitis, polynephritis, **Hurler's disease** (deformed bones due to accumulation of mucopolysaccharides). Storage of residual bodies also enhances the ageing processes.

(j) Lysosomes of osteoclasts digest the cartilage during the formation of replacing bones.

(k) Lysosomal enzymes of **seeds** help in digestion of proteins and starch so help in their **germination.**

Table 12. Differentiate between Heterophagy and Autophagy.

Characters	Heterophagy	Autophagy
1. Nature of food digested	Exogenous material of high molecular weight.	Endogenous cytoplasmic material and either reserve food or certain cell-organelles.
3. Period of occurrence	During abundance of food supply.	During starvation or diseased conditions.

Table 13. Differences between Autophagy and Autolysis.

Characters	Autophagy	Autolysis
1. Nature of food digested	Reserve food or some cellular organelle is digested.	Whole cell is digested.
2. Position of enzymes	Enzymes remain within the vacuole.	Lysosomal enzymes are released in the cytoplasm.
3. Period of occurrence	Occurs during starvation or pathological condition.	Occurs after the ageing or death of the cell.

D. RIBOSOMES

1. Discovery. These were first isolated from cell cytoplasm by **Claude** (1943 A.D.) and were named as **"microsomes".** These were reported in plant cell by **Robinson** and **Brown** (1953). These were called **'ribosomes'** by **G. Palade** (1955 A.D.).

2. Definition. The ribosomes are smallest known electron microscopic, sub-microscopic, ribonucleo-protein particles attached either on RER or floating freely in the cytoplasm and are the sites of protein synthesis.

3. Occurrence. These are found in both prokaryotes as well as eukaryotes (except mature sperm and RBC). In the prokaryotes these are present only in free form in the cytoplasm while in eukaryotes the ribosomes are found in two forms in the cytoplasm (**cytoplasmic ribosomes**) : **free-form** and **bound-form** (on RER and outer nuclear membrane). These are also reported inside some cell-organelles like mitochondria and plastids (called **organellar ribosomes**) respectively called **mitoribosomes** and **plastidoribosomes.**

4. Number. The number of ribosomes depends upon the RNA contents of the cell. These are more in plasma cells, liver cells, Nissl's granules of nerve cells, meristematic cells, cancer cells, endocrine cells etc.

5. Types. On the basis of **sedimentation co-efficient** (speed of sedimentation in the ultracentrifuge. $S = 1 \times 10^{-13}$ cm./sec./dyne/gm.), ribosomes are of **two types (Fig. 28)** :

(a) 70S ribosomes. These are found in the prokaryotes, and mitochondria and plastids of eukaryotes. Each is about 200-290Å × 170-210Å in size and 2.7×10^6 daltons (1 Dalton = 1.65×10^{-24} gm.) in molecular weight. Their sedimentation coefficient is 70S.

(b) 80S ribosomes. These are found in the cytoplasm of eukaryotes. Each is about 300-340 Å × 200-240Å in size and 4.5—5.0 × 10^6 daltons. Their sedimentation coefficient is 80S.

6. Structure. Each ribosome is formed of two unequal subunits (**Fig. 28**). Two subunits of 70S are : larger 50S and smaller 30S. Two subunits of 80S ribosomes are : larger 60S and smaller 40S. **Ribosome is not covered by any unit membrane** so is called **naked organelle.** It is called **subcellular organelle.**

Larger subunits is dome–shaped and is attached to ER by glycoproteins called **ribophorins.** It has a depression on the flat side which leads into a channel having elongating polypeptide chain. It also has two binding sites : **Peptidyl or P or Donor site** and **Amino acyl or A or Acceptor site.** These sites are for the attachment of charged tRNAs.

Smaller subunit is ellipsoidal and fits as a cap on flat side of larger subunits. It has binding site for mRNA.

7. Chemical composition. Ribosome is chemically called **ribonucleo-protein** (RNP) **particles.** Each ribosome is formed of rRNA and proteins e.g., 70S ribosome has 60-65% rRNA and 35-40% proteins. rRNAs are of three types : 23S type and 5S type rRNAs in 50S and 16S type rRNA in 30S sub-units. There are about 55 types of proteins in 70S ribosome out of which 21 proteins are found in 30S while 34 proteins are found in 50S ribosomal sub-unit and are called **core-proteins.**

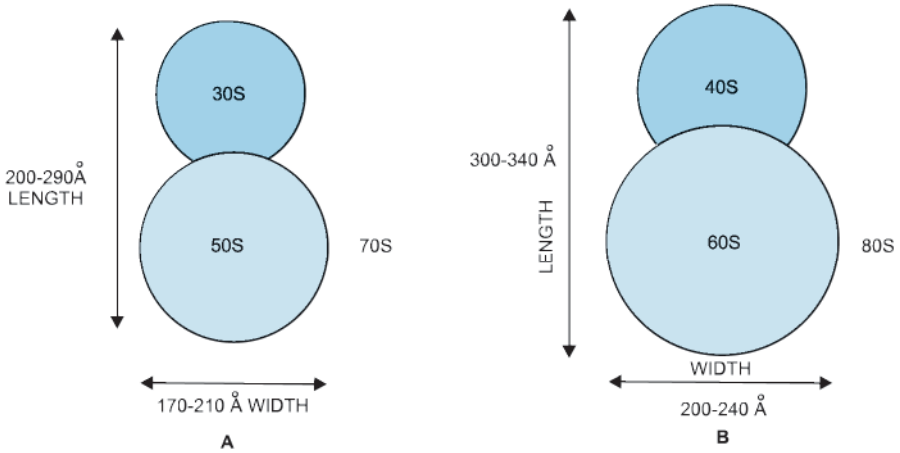


Fig. 28. Ribosomes—**A.** Prokaryotic. **B.** Eukaryotic.

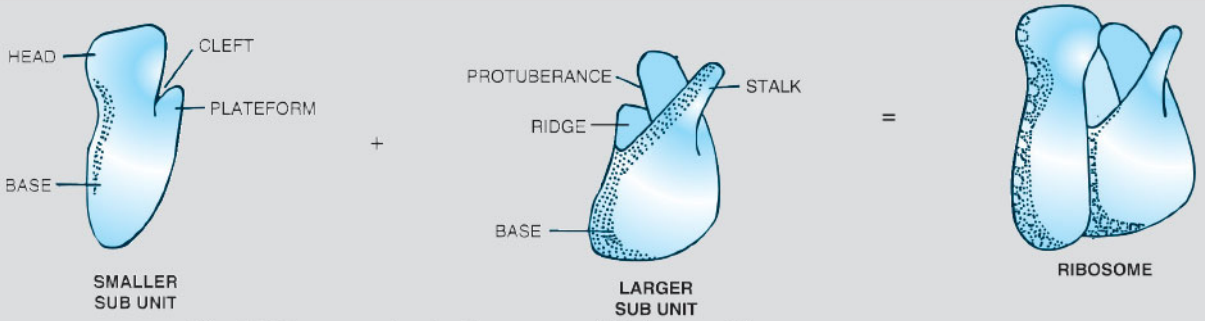


Fig. 29. Components of a ribosome and their association.

80S ribosome has 45% rRNA and 55% proteins. r-RNAs are of four types : 28S, 5S and 5.8S types of rRNAs in 60S and 18S type rRNA in 40S sub-units. There are about 70 types of proteins in 80S ribosome out of which 30 proteins are found in 40S while 40 proteins are found in 60S ribosomal sub-units.

Association of two subunits of Ribosome (Fig. 29)

James A. Lake (1981) gave the ultrastructure of two subunits of ribosome. The larger subunit has a broad **base, stalk, ridge** and a **protuberance,** while smaller subunit has a **base, plateform, cleft** and **head.** Two subunits are joined at the time of protein synthesis.

8. Polyribosome or Polysome. When many ribosomes are attached on same mRNA strand, it is called **polysome** or **polyribosome.** It is formed when a number of similar types of proteins are required. The number of ribosomes attached on mRNA depends upon the length of mRNA. The distance between adjacent ribosomes is of 90 nucleotides. Association and dissociation of ribosomal subunits depends upon Mg^{2+} concentration.

9. Functions :

(a) Ribosomes are called **protein-factories** or **engines of the cell** because these are sites of protein synthesis. Proteins control either cellular structure or act as enzymes and control cellular functions.

(b) Free ribosomes produce non-secretory proteins e.g. enzymes for intracellular use.

(c) Bound ribosomes on RER synthesize secretory proteins e.g. enzymes for extracellular use e.g., pancreatic cells, liver cells, plasma cells (antibodies) etc.

Table 14. Differences between Prokaryotic and Eukaryotic ribosome.

Characters	Prokaryotic ribosome	Eukaryotic ribosome
1. Sedimentation coefficient	70S	80S
2. Size	200-290Å	300-340Å
3. Molecular weight	2.8×10^6 daltons	$4.5\text{-}5.0 \times 10^6$ daltons
4. Number of RNAs	3 types	4 types
5. Large subunit		
(a) Sedimentation coefficient	50S	60S
(b) Molecular weight	1.8×10^6	$3\text{-}3.5 \times 10^6$
(c) RNA		
(i) types	2	3
(ii) Sedimentation and molecular weight	23S 5S 5S	28S 5.8S
(d) Proteins	34	40
6. Small subunit		
(a) Sedimentation coefficient	30S	40S
(b) Molecular weight	0.9×10^6	$1.5\text{-}1.8 \times 10^6$
(c) rRNA — its sedimentation rate and molecular weight	16S 0.6×10^6	18S 0.7×10^6
(d) Proteins	21	30

SUPPLEMENT YOUR KNOWLEDGE

- Nuclear membrane is also considered a part of endo-membrane system as its lumen is in continuation with the lumen of ER.
- **Sarcoplasmic reticulum :** A network of SER tubules present in the sarcoplasm of muscle fibres.
- Liver cells have both SER and RER.
- Golgi apparatus forms about 2 % of total cell volume.
- Main enzyme present on Golgi body membrane is **Nucleoside diphosphatase.**
- Lysosomes were earlier called **pericanalicular dense bodies.**
- **Ambilysosome :** Lysosome in which both heterophagy and autophagy go on simultaneously.
- Lysosomes are also called **recycling centres.**

PRACTICE PROBLEMS – ER, RIBOSOMES, GOLGI BODY AND MICROBODIES

52. What are cell organelles? Name two cell organelles.
53. Name two types of ER. Give one major difference between them.
54. Name three types of elements of ER.
55. Give one major function of SER.
56. Give one major function of RER.
57. Why are the ribosomes called RNP particles?
58. Name two types of ribosomes. Give their occurrence.
59. Define polysome.
60. Why are the ribosomes called protein–factories of the cell?
61. Who discovered Golgi body?
62. What are dictyosomes?
63. Name three types of elements of Golgi body.
64. List two major functions of Golgi body.
65. Which part of sperm is formed from Golgi body of a spermatid?
66. Which cell organelle is called suicidal bag?
67. Why is the lysosome called a polymorphic organelle?
68. What is residual body?
69. Why are the lysosomes called acidic hydrolases?
70. What is autolysis?

ANSWERS TO PRACTICE PROBLEMS

52. Living cytoplasmic structures are called cell organelles e.g. Ribosomes, ER, etc.
53. SER and RER. SER is without ribosomes while RER is studded with ribosomes.
54. Cisternae, vacuoles and tubules.
55. SER is involved in the biosynthesis of lipids, phospholipids, steroids, etc.
56. RER is involved in the biosynthesis of proteins.
57. Ribosomes are chemically formed of r-RNA and proteins.
58. 70S and 80S types of ribosomes. 70S ribosomes are found in prokaryotic cells, while 80S ribosomes are found in the cytoplasm of eukaryotic cells.
59. When a large number of ribosomes are attached on same strand of mRNA.
60. These are sites of protein synthesis.
61. Camilo Golgi (1898).
62. Scattered golgi bodies in the plant cells.
63. Cisternae, vesicles and vacuoles.
64. Cellular secretion, condensation membrane and formation of acrosome.
65. Acrosome of sperm.
66. Lysosome.
67. Lysosome occurs in four forms so is called polymorphic organelle.
68. Tertiary lysosome with only undigested food is called residual body.
69. Lysosomal enzymes are hydrolytic in nature and operate at 5.0 pH.
70. Self-digestion of cells after cell death is called autolysis.

ADDITIONAL USEFUL INFORMATIONS ABOUT ER, RIBOSOMES, GOLGI BODY AND MICROBODIES FOR COMPETITIVE EXAMINATIONS

*A. **ENDOPLASMIC RETICULUM :***

- *RER was named **ergastoplasm** by **Garnier** (1897).*
- ***Sjostrand :** called RER as **α-cytomembrane.***
- ***Ribophorin :** A glycoprotein which binds ribosomes on protoplasmic face of ER.*
- ***Myeloid bodies :** Reported by **Porter and Yamada** (1960). These are masses of tubules (so SER) found in retinal cells and are related with **photoreception.***
- ***Palade** (1956) called ER as **cell-circulatory system.***
- ***Protein trafficking :** Process of directing proteins to their final sites.*
- *Detoxification of harmful compounds by SER is brought by **cytochrome-P 450**.*
- ***Glycosomes :** Glycogen granules-rich ER tubules of the liver cells.*

B. GOLGI BODY :

- *Golgi body was first discovered by **silver impregnation method.***
- ***Dictyokinesis :** Division of Golgi complex (**Perroncito,** 1910).*
- ***Zone of exclusion :** A zone of clear cytoplasm with no ribosomes, mitochondria etc. around the Golgi complex.*
- *In Golgi body, the materials are transported from cis to trans face.*
- ***GERL :** Golgi-endoplasmic reticulum-lysosome system.*
- ***Glycosylation :** Combining the polysaccharides with the proteins to form glycoproteins in Golgi body.*
- ***Glycosylation of lipids :** Combining the polysaccharides with the lipids to form glycolipids in Golgi body.*
- *Golgi body is called **pleomorphic organelle** as its shape varies not only in different cell types but also with functional state of the cell.*
- *Glycosylation occurs in the presence of enzyme **glycosyl transferase** present on cisternal membrane.*

C. LYSOSOMES :

- *Cholesterol, cortisol and cortisone act as **stabilizers** of lysosomal membrane, while absence of oxygen, X-rays, UV-rays and excess of vitamin A and E. act as **labilizers** and weaken the lysosomal membrane.*
- ***Acid phosphatase** enzyme is employed as a marker for the lysosomes.*
- ***de Robertis et. al.** (1971) : Described polymorphism in lysosomes.*
- *Primary lysosomes are also called **protolysosomes** or **inactive lysosomes** or **original lysosomes.***
- *Autophagosomes are also called **autophagic vacuoles** or **cytolysosomes** or **autolysosomes**.*
- *Acidic medium in lysosome is maintained by **proton pump**.*
- *Autolysis is also reported in the **pupal stage** of insects and **involution** of uterus and mammary glands during the postpartem period (after birth).*
- ***Transosomes :** Cell organelles having **triple unit membrane** and are found in follicular cells of ovaries of birds. First reported by **Press** (1964).*

D. RIBOSOMES :

- *Ribosomes are also called **Palade particles.***
- *Ribosomes are **smallest** known cell organelles.*
- *Ribosomes form about 25-30% of a bacterial cell.*
- *During protein synthesis, m-RNA is read by smaller subunit of the ribosome.*
- ***Ribophorin**: A glycoprotein which attaches larger sub unit of ribosome on ER.*
- ***Polysome :** Also called **polyribosome** or **ergosome.** It was reported by **Rich et. al.** (1963)*
- *Prokaryotic ribosomes are found in only free form and are called **monosomes.***
- ***Svedberg unit (S) :** Rate of sedimentation of particles per unit of gravitational force.*
- *23S-rRNA of 50S subunit of 70S ribosome of prokaryotic cells acts as structural RNA as well as ribozyme.*

E. MITOCHONDRIA

1. Discovery. These were first discovered by **Kolliker** (1880 A.D.) in the voluntary muscles of flight in insects andwere called **granules**. Term mitochondrion (Gr. *mito* = thread; *chondrion* = granule) was given by **C. Benda** (1897 A.D.).

2. Occurrence. These are absent from prokaryotes but present in all eukaryotic cells except mature mammalian RBCs.

3. Shape. The shape is variable and may be granular, fibrillar, spherical (e.g. yeast), oval, sausage or discoidal so are **pleomorphic organelles**.

4. Size. It is also variable but depends upon the metabolic state of a cell. Average size of mitochondria is 1-4 µm in length and 0.2–1.0 µm in diameter. These are visible under light microscope.

5. Number and position. The number of mitochondria is also variable and depends upon the metabolic rate of the cell. These are more in growing, dividing and metabolically active cells. Minimum number of mitochondria is one in yeast, *Chlamydomonas*, *Chlorella*, etc. and certain protozoans e.g. *Trypanosoma*, *Micromonas*, etc. Maximum number of mitochondria are found in flight muscle cell of insect (500,000 per cell).

6. Ultrastructure (Fig. 30). A mitochondrion is formed of two limiting membranes and two chambers each having specific amzymes :

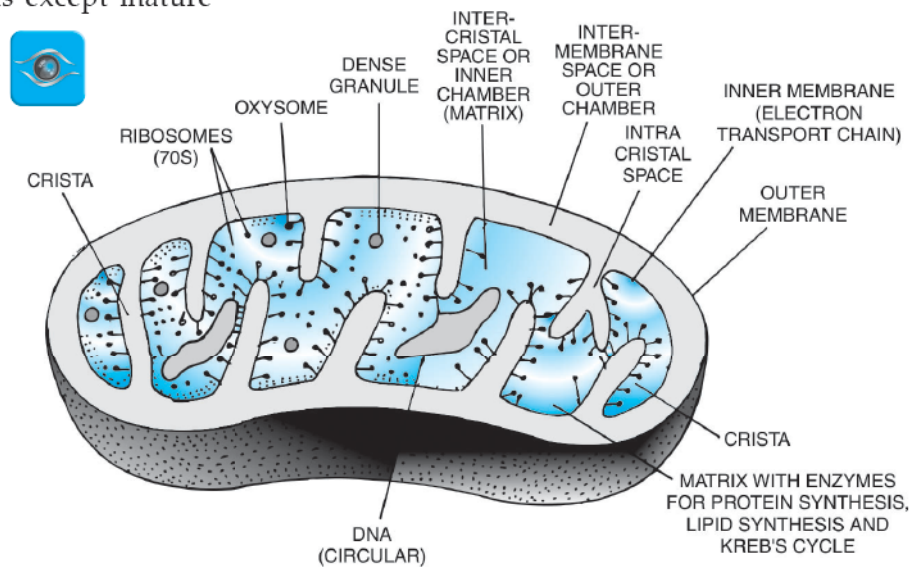


Fig. 30. Diagram of a Mitochondrion in section.

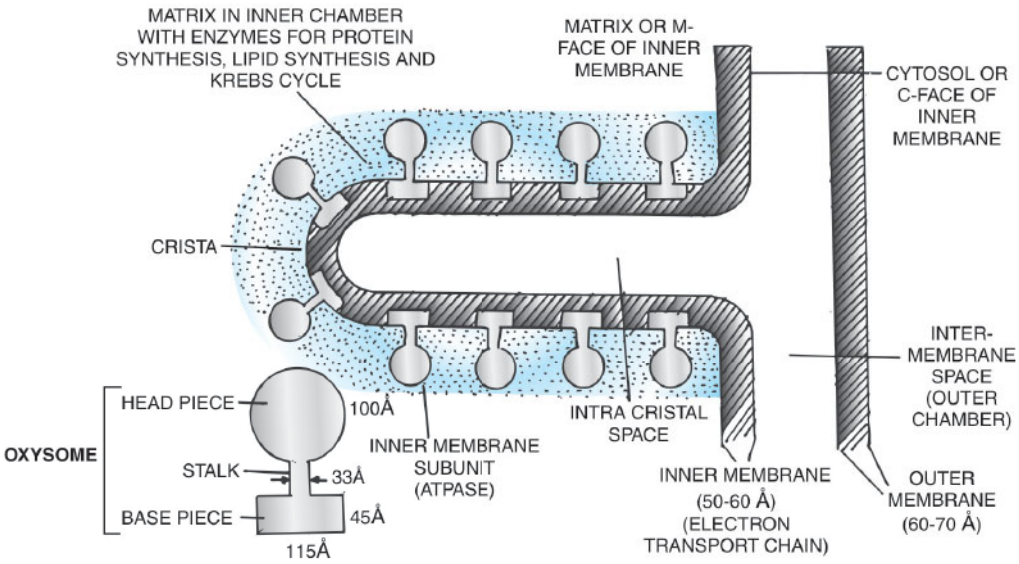


Fig. 31. Detailed structure of Crista and Oxysome.

(a) Mitochondrial membranes. These are two in number which form an envelope like a **thermos bottle.** Each is 60Å thick and is lipoproteinous and trilaminar. Outer membrane is with less proteins and is freely permeable while inner membrane is with more proteins and is semipermeable.

Outer membrane is smooth while inner membrane is produced inward into a number of folds called **cristae** which increase surface area of cell respiration. These cristae may be branched or unbranched, tubular **(tubuli)** or filiform (finger-like) and incomplete or complete. The number of cristae depends upon size of mitochondrion and metabolic rate of cell. Each crista has an **intra-cristal space** which is continuous with outer chamber. On the M-face (matrix) of inner membrane, there is a series of regularly placed knob-like **F_1 particles** or **elementary particles** or **oxysomes;** and enzymes and electron carrier molecules of electron transport chain, so are called **ETP** or **Electron transfer particles (Fig. 31).** Each F_1 particle is formed of three parts:

(i) Base Piece (F_0-subunit). It is a rectangular and embedded in inner membrane.

(ii) Stalk (F_5-F_6 subunit). It lifts the head.

(iii) Head Piece (F_1-subunit). It is spherical.

Number of F_1 particles per mitochondrion varies from 10,000 to 100,000. In the head of F_1 particles, enzyme **ATP synthetase** is present which controls synthesis of ATP, so these are also called **ATP-particles.**

(b) Mitochondrial chambers:

(i) Outer or Inter-membranous chamber or Perimitochondrial space. It lies between two membranes. It is filled with less denser medium formed of water, minerals, enzymes etc.

(ii) Inner chamber. It lies inside inner membrane. It is filled with a more denser and granular **mitochondrial matrix** which contains enzymes of protein synthesis, lipid synthesis and Krebs cycle.

Mitochondrial matrix also contains 70S ribosomes, called **mitoribosomes**, a number (2-6 in number) of circular and naked mt-DNA molecules, riboflavin, granules of calcium phosphate and divalent (Mn^{++} or Mg^{++}) ions.

7. Semi-autonomous nature of mitochondrion. Mitochondria contain all requirements of protein synthesis :

(a) 70S ribosomes.

(b) DNA molecules to form mRNA.

(c) ATP molecules to provide energy.

The mitochondria can form some of the required proteins but for most of proteins, these are dependent upon nuclear DNA and cytoplasmic 80S ribosomes, so are called **semi-autonomous organelles.**

8. Functions

(a) Mitochondria are called **power houses or storage batteries** or **ATP mills** as these are sites of ATP formation.

(b) Also the site of **thermiogenesis.**

(c) Yolk nucleus (a mitochondrial cloud and Golgi bodies) controls **vitellogenesis.**

Table 15. Differences between Outer and Inner mitochondrial membranes.

Characters	Outer membrane	Inner membrane
1. Cristae	Absent.	Present.
2. Permeability	Freely permeable.	Semipermeable.
3. Proteins	50% proteins.	80% proteins.
4. Nature of lipids	Large amount of cholesterol.	Large amount of cardiolipids but no cholesterol.

(d) Mitochondria of spermatid form **nebenkern** (middle piece) of sperm during spermiogenesis.

(e) Mitochondrial matrix has enzymes for elongation of fatty acid chains.

9. Similarities between mitochondria and bacteria

(i) Cristae of mitochondria are similar to **mesosomes** of bacterial membrane.

(ii) DNA is circular, double-stranded and naked.

(iii) Both multiply by **binary fission.**

(iv) Both have **70S** type of ribosomes.

10. Origin. New mitochondria are formed by **binary fission** of pre-existing mitochondria.

F. PLASTIDS

1. Term plastid was given by **Haeckel** (1866 A.D.).

2. Occurrence. These are found in all plant cells and some protists (e.g. **Euglenoids**) and **diatoms** and are light microscopic structures.

3. Types. These have specific function and pigments on the basis of which plastids are of **two types :**

(a) Leucoplasts and **(b) Chromoplasts.**

(a) Leucoplasts (*leuco*=white). These are largest sized colourless plastids and have no grana and chlorophyll. These are found in those parts of plant which are not exposed to light e.g., roots, rhizome, seeds etc. and are involved in **storage of food**.

(b) Chromoplasts (Gr. *chroma* = colour). These are pigmented, so are coloured and are found in those parts which are exposed to light e.g., leaves, flowers etc. These are involved in photosynthesis, pollination or dispersal of seeds or fruits.

Types of Leucoplasts. These are of **three types** on the basis of **nature of food stored :**

(i) Amyloplasts. These **store starch** and are found in potato tubers and grains of wheat and rice.

(ii) Aleuroplasts or **Proteinoplasts.** These **store proteins** and are found in maize grains.

(iii) Elaioplasts or Oleoplasts. These **store fats** and are found in seeds of castor, mustard, groundnut etc.

Types of Chromoplasts. On the basis of **pigments** present, chromoplasts are of **three types :**

(i) Chloroplasts (Autoplasts). These are **green plastids** and contain **chlorophyll** and **carotenoids.**

(ii) Phaeoplasts. These are found in brown algae and contain **xanthophylls** and **fucoxanthin.**

(iii) Rhodoplasts. These are found in **red algae** and contain red pigment **phycoerythrin.**

CHLOROPLAST
(Gr. *chloros* = green ; *plastos* = formed)

Chloroplast was discovered by **Anton Von Leeuwenhoek.** Term '**chloroplast**' was given by **Schimper** (1883 A.D.).

2. Occurrence. These are **most common type of plastids** found in the photosynthetic mesophyll cells of leaves and green stem. Also found in some protists e.g., *Euglena.* These are absent from bacteria, cyanobacteria, fungi and animals.

3. Shape. It varies widely. It is cup-shaped in *Chlamydomonas*, spiral ribbon-like in *Spirogyra*, girdle-shaped in *Ulothrix*, branched and star-like in *Zygnema*. In higher plants, it is spherical, oval or discoidal.

4. Number also varies e.g., only one chloroplast in *Chlamydomonas* and *Ulothrix*, 1-16 chloroplasts in *Spirogyra*, 20-40 chloroplasts per cell in higher plants but an internodal cell of *Chara* has several hundred chloroplasts.

5. Size. Average size is 5–10 μm long and 2–4 μm in diameter .

6. Ultrastructure (Fig. 32)

(a) Limiting membranes. These are two in number. Each is 40-60Å thick, lipoproteinous and trilaminar. Outer membrane has less proteins and is more permeable while inner membrane has more proteins and is semipermeable. Between two membranes, there is a fluid-filled inter-membranous **periplastidial space.**

(b) Stroma or matrix. It is denser and granular ground substance present inside the inner membrane. It is formed of soluble proteins (more than 50%) and also has 70S ribosomes **(plastidoribosomes),** circular and naked DNA molecules called **plastidome**, mRNA and tRNA molecules, water, minerals (Mn^{2+}, Fe^{2+}, Mg^{2+}) and enzymes. It is the site of **CO_2 fixation** and **protein synthesis**. Most common enzymatic protein is **Ribulose biphosphate carboxylase (Rubisco).**

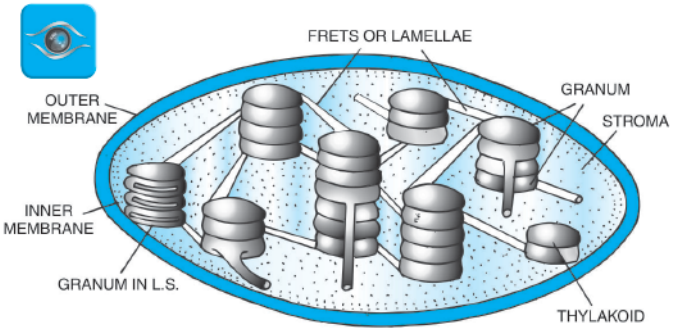


Fig. 32. Ultrastructure of Chloroplast.

Table 16. Differences between Leucoplasts and Chromoplasts.

Characters	Leucoplasts	Chromoplasts
1. Pigment	Without pigment so are **colourless plastids.**	**Coloured plastids** due to the presence of pigments.
2. Occurrence	These are found in **underground** parts like roots, rhizome, tubers, seeds etc.	These are found in **aerial parts** like leaves, flowers, fruits etc.
3 Function	Store the reserve food e.g., **Amyloplasts** store starch, **Elaioplasts** store fats.	Help in **photosynthesis, pollination** or **dispersal** of seeds or fruits.

Table 17. Differences between Mitochondria and Chloroplasts.

Characters	Mitochondria	Chloroplasts
1. Occurrence	Found in all the types of cells of aerobic organisms.	Found only in green cells of plants and some protists.
2. Shape	Generally rod-shaped or thread-like.	Generally discoidal.
3. Inner membrane	Produced into finger-like or tubular infolds, called **cristae**, which do not separate. Grana are absent.	Produced into flattened sacs, called **thylakoids**, which separate and form grana.
4. Pigments	Absent.	Thylakoid membranes have photosynthetic pigments.
5. Function	Sites of **cell respiration** in which oxygen is consumed and CO_2 and ATP molecules are produced.	Sites of **photosynthesis** in which CO_2 is consumed and O_2 and organic food are produced.

(c) Grana. Inner plastidial membrane is invaginated to form a number of oval – shaped closed sacs, called **thylakoids**. **Thylakoids are structural and functional elements of chloroplasts.** These thylakoids contain all the requirements of light reactions e.g. pigments like chlorophyll, carotenoids, plastoquinone, plastocyanin, etc. that are involved in photosynthesis. Each thylakoid has an intra-thylakoid space, called **loculus** bounded by a unit membrane. Along the inner side of thylakoid membrane, there are a number of small rounded para-crystalline bodies, called **quantasomes** (a quantasome is the **photosynthetic unit**), which can trap a mole of quantum of light and can bring about photosynthetic act. Each quantasome contains about 230 chlorophyll molecules and other photosynthetic pigments.

In eukaryotic plant cells, a number of thylakoids are superimposed like a pile of coins to form a **granum**. The number of thylakoids in a granum ranges from 10-100. The number of grana per chloroplast also varies widely e.g., one granum per chloroplast in *Euglena* while there are 40-60 grana per chloroplast in spinach.

Adjacent grana are interconnected by flat tubules, called **stromal lamellae or frets**.

7. Semi-autonomous nature. Like the mitochondria, the chloroplasts are semi-autonomous organelles because these have complete machinery (e.g. DNA, RNAs, ribosomes and ATP) to synthesize some proteins while for some other proteins these depend upon nuclear DNA and cytoplasmic ribosomes.

8. Functions

(a) These are the sites of **photosynthesis**, so are called **kitchens of cell.**

(b) These evolve **oxygen for respiration**.

(c) These **store the starch** in the proteinaceous bodies called **pyrenoids** in algal forms.

REMEMBER

- In giant amoeba *Chaos chaos*, there are about 50,000 mitochondria.
- Mitochondria and chloroplasts are self-duplicating cell organelles as contain DNA.
- Plastids develop from colourless precursors called **proplastids**.
- **Chromoplasts** are formed either from chloroplasts by replacement of chlorophyll with other pigments (*e.g.*, **lycopin** in tomatoes and **capsanthin** in red pepper) or from the leucoplasts by development of some pigments (*e.g.*, **carotenes** in carrot root cells).

PRACTICE PROBLEMS – MITOCHONDRIA AND PLASTIDS

71. Who discovered the mitochondria?
72. Who coined the term mitochondrion?
73. Why are the mitochondria more in growing, dividing and active cells?
74. What are cristae? Give their function.
75. Define oxysomes.
76. What are mitoribosomes?
77. Why are the oxysomes called ATP particles?
78. Why are the mitochondria and plastids called semiautonomous organelles?
79. Why are the mitochondria called power houses of the cell?
80. Give one major difference between leucoplasts and chromoplasts.
81. Name the stored food of amyloplasts, aleuroplasts and elaioplasts.
82. What are plastidoribosomes?
83. Name the structural and functional elements of chloroplasts.
84. What are quantasomes? Why are these called photosynthetic units?
85. What is a granum?
86. Why are the plastids called kitchens of the cell?

ANSWERS TO PRACTICE PROBLEMS

71. Kolliker (1880).
72. C. Benda (1897).
73. Due to their higher metabolic rate and more energy dependency.
74. These are infolds of inner mitochondrial membrane which increase the surface area for the respiratory enzymes.
75. These are knob-like elementary particles present on the m-face of inner mitochondrial membrane.
76. These are 70S type ribosomes present in the mitochondrial matrix.
77. As enzyme ATP synthetase is present in the head of the oxysomes.
78. These organelles can synthesize some proteins but for other proteins these are dependent upon nuclear DNA and cytoplasmic ribosomes.
79. These are sites of oxidation of glucose and ATP formation.
80. Leucoplasts are colourless plastids, while chromoplasts are coloured plastids.
81. Amyloplasts store starch, aleuroplasts store proteins and elaioplasts store fats.
82. These are 70S ribosomes found in the matrix of chloroplast.
83. Thyaloids.
84. These are rounded, para-crystalline bodies present along inner surface of thylakoid membrane. These have chlorophyll molecules which can trap the radiant energy of sunlight.
85. A stack of thylakoids is called granum.
86. Because these are the sites of photosynthesis.

ADDITIONAL USEFUL INFORMATIONS ABOUT MITOCHONDRIA AND PLASTIDS FOR COMPETITIVE EXAMINATIONS

*A. **MITOCHONDRION :***

- ***Scientists associated with the mitochondria :***
  - ***Altmann** (1890) : Gave the term **'bioplast'** and considered the mitochondria as **symbiotic bacteria.***
  - ***Michaelis** (1900) : Stained mitochondria with vital stain **- Janus green B.** (Specific stain for mitochondria).*
  - ***Palade and Sjostrand** (1935) : Described ultrastructure of mitochondria.*
  - ***H. Fernandes-Moran** (1963) : Reported F_1-particles along inner mitochondrial membrane.*
  - ***Nass and Afzelius** (1965) : Reported mitochondrial DNA.*
  - ***Phillip Siekwitz (1957)** : Called mitochondria as **"power house"** of the cell.*
  - ***Peter Mitchel (1978)** : Proposed **chemio-smosis** theory of ATP formation.*
- *Mitochondria take part in **energy transformation**, called **bioenergetics**, of cells.*
- *These are **largest cell organelles** in animal cell and **second largest organelles** in plant cells. These are **third largest structure** of plant cell after nucleus and plastid. In plants, plastids are largest sized cell organelles.*
- ***Sarcosomes :** Mitochondria of sarcoplasm of muscle fibres.* ● ***Chondriosomes :** All the mitochondria present in a cell.*
- *Mitochondria are **more in animal cells than plant cells.***
- ***Mitochondria are more in germinating seeds** than dormant seeds.*
- *Mitochondria form about **25%** of cell volume.* ● *Functional units of mitochondria are **F_0–F_1 particles (oxysomes).***
- *Two mitochondrial membranes are **asymmetrical** in nature as are different in structure and function.*
- *Outer surface of inner mitochondrial membrane is called **C or Cytosol face**, while its inner surface is called **M or matrix face.***
- ***Proton channel** lies in F_0 subunit of oxysome; F_5 and F_6 lie in its stalk while enzyme **ATP synthetase** is present in its F_1 subunit.*
- ***Mitochondrial-DNA** is rich in G-C pairs than the nuclear DNA so with higher denaturation temperature. These form 1% of total cellular DNA. Mitochondrial genome shows many similarities to bacterial genome.*
- *About 70% of total cellular enzymes are reported in the mitochondria.*
- ***Mitoplasts:** Mitochondria without outer membrane.*

*B. **PLASTIDS :***

- ***Ris and Plaut** (1962) : Reported DNA in chloroplast and was called **plastidome.***
- *Photosynthetic pigments of higher plants are chlorophyll a, b carotenes and xanthophylls.*
- ***Transducers :** Structures which are involved in energy transformation e.g. **mitochondria** and **plastids.***
- ***C_3 plants** have **monomorphic chloroplasts** only in their mesophyll cells, while **C_4-plants** show **dimorphism** in their chloroplasts (called **Kranz anatomy) : Agranal** (without grana) **chloroplasts** are found in bundle sheath cells while **Granal** (with grana) **chloroplasts** are found in mesophyll cells of C_4 plants.*
- ***Chromatophores :** Scattered thylakoids in the cytoplasm of cyanobacteria and photosynthetic bacteria.*

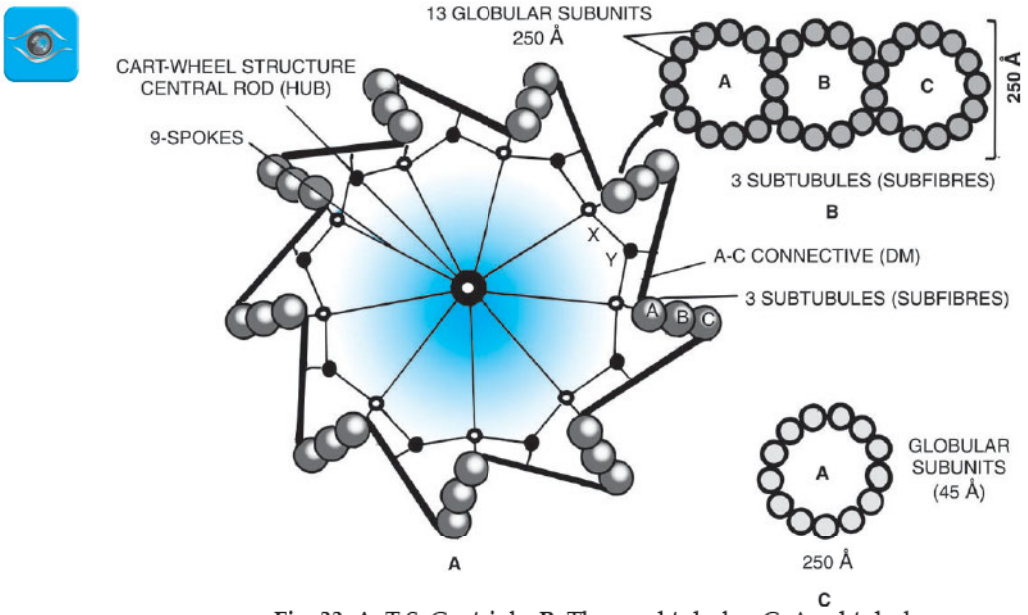


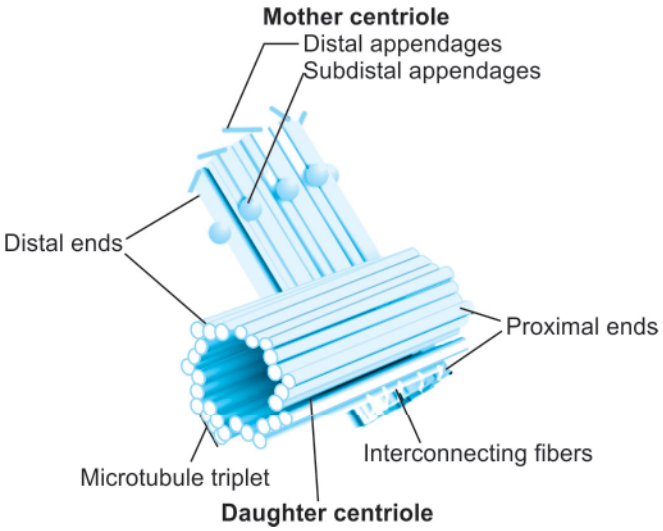
Fig. 33. A. T.S. Centriole. **B.** Three subtubules. **C.** A subtubule.

G. CENTRIOLE (Gr. *kentron* = centre)

1. Discovery. Centriole, also called **cell-centre,** was first discovered by **Van Benden** (1887 A.D.). Its structure was given by **T. Boveri** (1888 A.D.).

2. Occurrence. It is a light microscopic organelle found in all the animal cells except mature mammalian RBCs. It is also found in most of protists and flagellated plant cells like antherozoids of ferns, zoospores of algae and motile algal forms e.g., *Chlamydomonas*, but is absent in prokaryotes, members of the fungi and higher plants.

3. Light-microscopic structure. Centrosome is formed of two darkly stained granules, called **centrioles**, which are collectively called **diplosome.** These centrioles are surrounded by an amorphous and transparent cytoplasmic area called **centrosphere** or **cytocentrum.** Centrioles and centrosphere are collectively called **centrosome.**



Diplosome

4. Ultrastructure (Fig. 33). Under EM, two centrioles are hollow cylinders perpendicular to each other. Each centriole is a **microtubular structure** and is formed of microtubules arranged in **9+0 manner.**

Each microtubule is a **triplet** and is formed of three subtubules which are called **A, B** and **C. A** subtubule is formed of 13 parallel **protofilaments** while each of **B** and **C** subtubule is formed of 10 parallel **protofilaments.** Each protofilament is formed of a row of α β - tubulin dimers. **C** sub-tubule of each microtubule is linked to **A** sub-tubule of adjacent microtubule by a dense material (DM) strand called **A-C linker,** so all the microtubules are tilted at 40°. Each microtubule is 250Å in diameter.

Inside the microtubules, there is an **intra-centriolar** or **cart-wheel structure** which is formed of a central proteinous **hub** and 9 proteinous **radial spokes** or **radial fibres.** Each radial spoke ends into a dense material thickening, called **X-body** or **foot,** which is further linked to **A**-subtubule. Between two adjacent X-bodies there is another DM-thickening, called **Y-body,** which is linked to X-body on either side and to A-C linker on outer side.

Each centriole is surrounded by two **pericentriolar structures** also called **crowns** or **massules** or **satellites**. Each pericentriolar structure is formed of 9 rounded thickenings, (called **sphaeroids** or **corpuscles**) one linked to each microtubule. These help in formation of new centrioles in G_2 phase of cell cycle and regulate the growth of microtubules during aster formation and duplication of centrioles, so called **nucleating centres.**

5. Chemical composition.

Proteins = 60-70% (Main protein type is **tubulin**)

Lipids = 17-23%, Nucleotides = 0.4%

6. Functions

(a) The centrioles form **asters** during cell division of animal cells (called **amphiastral**).

(b) These also form **basal-bodies.**

(c) Distal centriole of sperm gives rise to **axoneme** or **axial filament** of sperm-tail.

H. BASAL BODIES

These are also called **basal granule** or **blepharoplast** or **kinetosome.** The basal body resembles the centriole in its shape, chemistry and ultrastructure (9 + 0 microtubular plan) but differs from it in following characters (Table 18) :

I. CILIA AND FLAGELLA

1. Discovery. Flagellum presence was first reported by **Englemann** (1868 A.D.). **Jansen** (1887 A.D.) was first scientist to explain structure of sperm flagellum.

2. Definition. These are microscopic, hair or thread-like motile structures present extra-cellularly but originate intra-cellularly from the basal body and help in locomotion, feeding, circulation etc.

3. Occurrence. Cilia are found in all the ciliate protozoans e.g., *Paramecium*, etc; Flame cells of flat worms; in some larvae e.g., *Trochophore* larva of *Nereis*, *Bipinnaria* larva of **starfish** etc.; in some body-structures *e.g.*, wind-pipe, fallopian tubes, kidney-nephrons etc.

Flagella are found in flagellate protozoans e.g., *Euglena*, etc.; **collar cells** of sponges; **gastrodermal cells** of coelenterates; **spermatozoa** of animals; **zoospores** of algae etc. These are absent in red algae, blue-green algae, angiosperms, Nematodes, arthropodes etc.

4. Ultrastructure (Fig. 34). A cilium or flagellum is formed of **two parts :**

(a) Protoplasmic sheath. It is outer and protective coat. It is continuous with the plasma-membrane.

(b) Axoneme or **axial filament.** It is central and contractile part. It is formed of **11 microtubules** arranged in **9 + 2 manner.** Microtubules are of **two types :**

(i) Central microtubules. These are two in number. Each is about 250Å in diameter. Each is formed of 13 **protofilaments,** each being formed of a row of αβ-tubulin dimers. Two central tubules are helically wound by a common **central sheath** and are also interconnected by double bridges.

(ii) Peripheral microtubules. These are 9 in number and are present along the periphery. Each is **doublet** and is formed of 2-subtubules :

A-subtubule is slightly inner and is formed of 13 globular protein molecules. It gives two arms in clockwise direction. Inner arm is attached to B-subtubule of adjacent microtubule by **interdoublet or B-A linkers** for their coordinated action while outer arm ends into a hook.

Each A-subtubule gives an inward directed proteinous **radial spoke,** which ends into **spoke-head,** near the central sheath.

B-subtubule is slightly outer in position and is formed of 10 globular protofilaments.

During ciliary or flagellar beating, spoke heads are connected to the central sheath of central microtubules, so there is coordination between microtubules.

5. Chemical composition. Chemically, the central tubules are formed of **dynein protein** while the peripheral microtubules are formed of **tubulin protein.** Dynein is the **ATPase enzyme** which hydrolyses the ATP to provide free energy for ciliary/flagellar beating. The interdoublet linkers are formed of **nexin protein.**

Table 18. Differences between Basal body and Centriole.

Characters	Basal body	Centriole
1. Position	In ectoplasm just beneath the cell-membrane.	Near the nucleus.
2. Number	More in number.	Only two in a cell.
3. Size	Larger (300-500 μm)	Smaller (0.3-0.5 μm).
4. Association	Always associated with cilium/flagellum.	Not associated with cilium/flagellum.
5. Rhizoplasts	Root-like processes called **rhizoplasts.**	No rhizoplasts.
6. Function	It controls the **movements** of **cilia and flagella.** It also gives rise to cilium/flagellum.	It helps in **cell-division and forms the aster.**

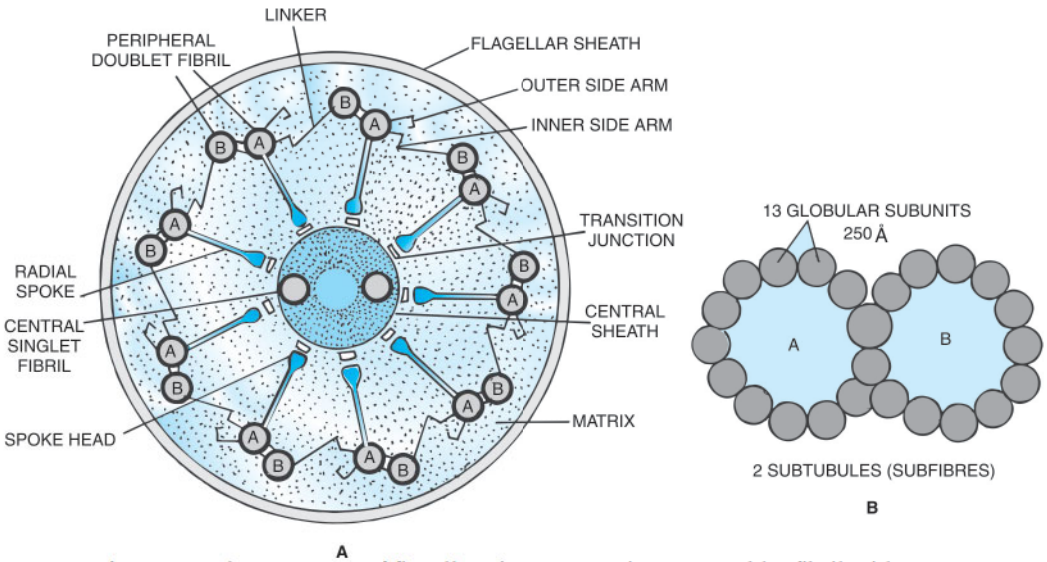


Fig. 34. A. Ultrastructure of flagellum in cross-section. **B.** Doublet fibril without arms.

6. Functions

(a) Cilia of *Paramecium* and flagellum of *Euglena* help in locomotion.

(b) Cilia of *Paramecium* and flagella of **collar cells** of sponges maintain a **nutritive-cum-respiratory water-current** inside the body.

(c) Cilia of wind pipe **expel out any dust or food particle.**

(d) Cilia of nephrons **move nephric filtrate.**

(e) Cilia of oviduct **move ovum.**

(f) Cilia of *Paramecium* also help in **conjugation.**

(g) Cilia of larval forms help in their **dispersal.**

7. Origin. Cilia and flagella arise from the basal bodies which are semi-autonomous.

8. Ciliary beating. Cilia beat either **metachronously (isochronously)** (cilia of transverse rows beat in coordination) or **synchronously** (cilia of longitudinal rows beat in coordination). The beating of cilia involves **sliding movements** of microtubules on one another. Each ciliary beat is formed of 2 strokes **(Fig. 35)** :

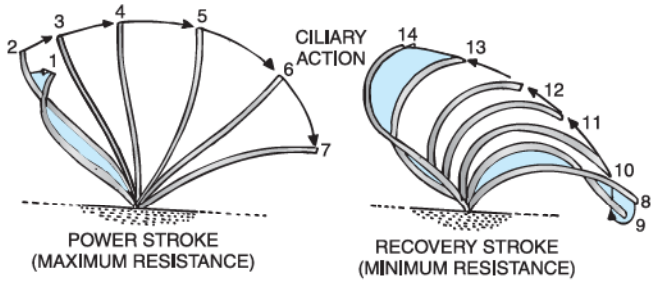


Fig. 35. Ciliary beating.

(a) Power or effective stroke. The cilium becomes stiff due to contraction of axoneme and moves backward as an oar. This gives **forward push.**

(b) Recovery stroke. The cilium becomes loose due to elasticity of protoplasmic sheath and moves forward in a flexed position to original position.

In ciliary beating, the power stroke is more powerful than recovery stroke and the ciliary beating is **like the rowing of a boat.**

9. Flagellar beating. It involves a **series of symmetrical undulating waves** passing from the base to tip of flagellum which push the organism in the direction opposite to that of the flagellum or from tip to base which pull the organism.

10. Similarities between Cilia and Flagella :

(a) Both arise **from the basal bodies.**

(b) Both are similar in their **ultrastructure.**

(c) Both have similar **chemical composition.**

(d) Both are similar in their **basic function.**

11. Differences between Cilia and Flagella (Table 19) :

J. CYTOSKELETAL STRUCTURES

These are two types of filamentous proteinous structures which form network in the cytoplasm.

I. MICROTUBULES

1. Discovery. These were first discovered by **Robertis and Franchi** (1953 A.D.) in the axons of medullated nerve fibres and were named **neurotubules.**

2. Position. The microtubules are electron-microscopic structures found only in the **eukaryotic cellular structures** like cilia, flagella, centriole, basal-body, astral fibres, spindle fibres, sperm tail, neuraxis of nerve fibres etc. These are absent from amoebae, slime-moulds and prokaryotes.

3. Structure (Fig. 36). A microtubule is a hollow cylindrical structure of about 250Å in diameter with about 150Å lumen. Its wall is about 50Å thick. Its wall is formed of 13 parallel, **prototubules,** each being formed of a linear series of globular α β-**dimeric protein molecules.**

4. Chemical composition. These are mainly formed of **tubulin protein.** A tubulin protein is formed of 2 sub-units : α-**tubulin** molecule and β-**tubulin** molecule which are alternatively in a helical manner. This gives definite polarity to the micro tubules.

Table 19. Differences between Cilia and Flagella.

Characters	Cilia	Flagella
1. Number	**More** in number (may be upto 14,000 per cell).	**Less** in number (1-8).
2. Size	**Small sized.**	**Large sized.**
3. Distribution	Generally distributed on **whole body.**	Generally located at **anterior end** of body.
4. Beating	Beat in either **metachronous or synchronous coordination.**	Beat **independently.**
5. Type of motion	**Sweeping or rowing motion.**	**Undulatory motion.**
6. Function	Locomotion, feeding, circulation etc.	Only locomotion

Table 20. Differences between Bacterial flagellum and Eukaryotic flagellum.

Characters	Bacterial flagellum	Eukaryotic flagellum
1. Sheath	Absent.	Sheath formed from the plasma membrane is present.
2. Size	Smaller, 1-7 µm long.	Longer, 100-200 µm long.
3. Structure	**Monofibrillar** (single stranded).	With **9 + 2 arrangement** of microtubules.
4. Chemical nature	Formed of **flagellin** protein.	**Tubulin,** dynein and nexin proteins.
5. Rhizoplasts	Absent.	Present.

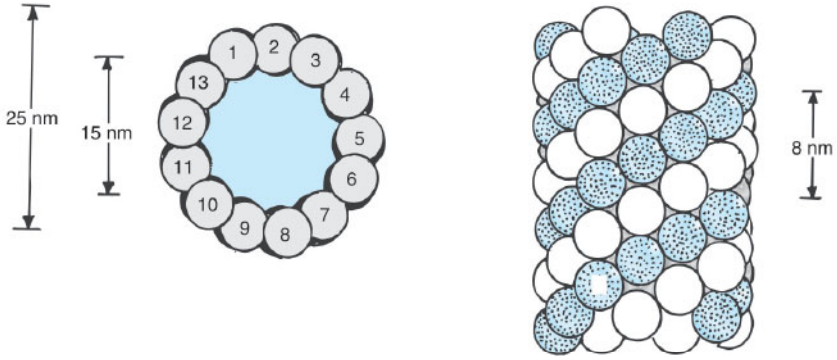


Fig. 36. Structure of Microtubule—showing probable arrangement of tubulin sub-unit.

5. Functions:

(a) These are stiff and form a part of **cytoskeleton** and help in **cell-shape** and **mechanical support.**

(b) The microtubules of cilia and flagella help in **locomotion** and **feeding.**

(c) The microtubules of asters and spindle fibres of the **mitotic apparatus** help in the movement of **chromosomes** in cell-division.

(d) The microtubules of neuraxis help in **conduction of nerve impulses.**

(e) These help in distribution of pigment in the chromatophores, so help in **skin colouration.**

(f) These also form **micro-circulatory system** of the cell which helps in **intracellular transport.**

(g) These control the **orientation of cellulose microfibrils in the cell wall** of plants.

II. MICROFILAMENTS

1. Position. These are electron-microscopic, long, narrow, cylindrical, solid, contractile and proteinous structures found only in the **eukaryotic cytoplasm.** These are present in the microvilli, muscle fibres (called **myofilaments)** etc. But these are absent from the prokaryotes. These are also associated with the pseudopodia, plasma membrane of fibroblasts, etc.

2. Discovery. These were discovered by **Paleviz** *et. al.* (1974).

3. Structure. Each microfilament is a solid filament of 50-60Å diameter and is formed of a helical series of globular protein molecules. These are generally grouped to form **bundles.**

4. Chemical composition. These are mainly formed of **actin-like protein.**

5. Functions : (a) These form a part of **cytoskeleton** so helps in **cell-shape** and **mechanical support.**

(b) These help in **cyclosis** of the cytoplasm.

(c) Microfilaments of the myofibrils of muscle fibres help in **movements and locomotion.**

(d) Microfilaments of microvilli help in their movements and **absorption of food.**

(e) These help in **intracellular movement** of cellular organelles.

(f) These help in **cytokinesis** in dividing animal cells.

(g) These help in **endocytosis** and **exocytosis** through the cell-membrane.

(h) These help in **amoeboid locomotion** found in leucocytes of blood; phagocytes of the connective tissue and amoeboid protozoans like *Amoeba.*

(i) These help in **undulatory movements** of plasma membrane of fibroblasts.

K. MICROBODIES

Microbodies are small-sized **single membrane-bound cell organelles** found in both plant and animal cells. Their matrix has specific types of enzymes for specific function e.g.

1. Peroxisomes. These were discovered by **De Duve** (1969). These are found in photosynthetic cells of plants and also in the liver and kidney cells of the vertebrates. Their matrix has oxidase and catalase enzymes which are involved in **formation and degrading of H_2O_2.** In plants, these participate in **photorespiration.**

2. Glyoxisomes. These were discovered by **Beevers** (1963). These are found in fat-rich plant cells. These are involved in **β-oxidation of fats** (conversion of fatty acid into Acetyl CO. A) **gluconeogenesis** (conversion of fats to carbohydrates) and **glyoxylate pathway.**

3. Sphaerosomes. These were discovered by **Pernar** (1953). These are found only in plant cells and are involved in formation and storage of fats. In some plant cells, these enzymes have hydrolytic activity and are called **plant lysosomes.**

Table 21. Differences between Microfilaments and Microtubules.

Microfilament	Microtubules
1. These are **contractile.**	1. These are **non-contractile.**
2. These do not possess longitudinal sub-units.	2. A microtubule contains **13 protofilaments.**
3. Microfilaments are **solid** structures.	3. They are **hollow** tubules.
4. Microfilaments are mainly made up of **actin.**	4. Microtubules are formed of **α** and **β–tubulin proteins.**
5. The diameter of a microfilament is **5-6 nm.**	5. The diameter of a microtubule is **25 nm.**

COMPETITION PLUS

- New centrioles are formed from pre-existing centrioles in G_2 phase of interphase.
- Cilia of some flatworms have **9+1** microtubular array in their axoneme, while cilia of Asian horse shoe crab have 9 + 0 microtubular array.
- **Cytoskeleton** is formed of microtubules, microfilaments and intermediate filaments. It helps in definite shape, mechanical support to the organelles and motility of the cell.

PRACTICE PROBLEMS – CENTRIOLE, BASAL BODY, CILIA, FLAGELLA, MICROTUBULES AND MICROFILAMENTS

87. Which cell organelle is called cell centre?
88. What is the arrangement of microtubules in centriole and basal body?
89. Give the chemical nature of the microtubules.
90. Give the main function of centrioles.
91. What do you mean by diplosome?
92. Which structure is called ciliated centriole?
93. List one major difference between centriole and basal body.
94. What is the arrangement of microtubules in cilia and flagella?
95. Give one difference between beating of cilia and flagella.
96. What is synchronous beating of cilia?
97. What is metachronous beating of cilia?
98. List two functions of microtubules.
99. Differentiate between the chemical nature of microtubules and microfilaments.
100. Which structures help in cyclosis of cytoplasm and cleavage of cell?

ANSWERS TO PRACTICE PROBLEMS

87. Centriole.
88. 9 + 0 microtubular arrangement.
89. Mainly formed of tubulin protein (60-70%).
90. These form the asters of the spindle during animal cell division.
91. A pair of centrioles is collectively called diplosome.
92. Basal body.
93. Centriole is not associated with cilium or flagellum while basal body is associated.
94. 9 + 2 microtubular arrangement.
95. Cilia beat in coordination like the rowing of a beat, while flagella beat independently by a series of symmetrical undulating waves.
96. In this, cilia of longitudinal rows beat in coordination.
97. In this, cilia of transverse rows beat in coordination.
98. These form the mitotic apparatus and cytoskeleton.
99. Microtubules are formed of tubulin protein, while microfilaments are formed of mainly actin protein.
100. Microfilaments.

ADDITIONAL USEFUL INFORMATION ABOUT CENTRIOLES, BASAL BODIES, CILIA, FLAGELLA, MICROTUBULES AND MICROFILAMENTS FOR COMPETITIVE EXAMINATIONS

A. CENTRIOLE AND BASAL BODIES :

- *Centriole is also called **microcentrum** or **cell centre.***
- *Centriole has high amounts of **ATPase enzyme.***
- *Each centriole is formed of 9 × 3 = 27 **subtubules** or **subfibres.***
- ***Wolfe** (1972) : **Basal body is a ciliated centriole.***
- *Basal body has a **basal plate** at the base while it is **capped** at the distal end, but there is no basal plate and cap in centriole.*

B. CILIA AND FLAGELLA :

- ***Hodge** gave ultrastructure of the flagellum of the sperm.*
- ***Manton** gave ultrastructure of cilium.*
- ***Kinocilia :** Motile cilia e.g. of epithelial cells of respiratory tract.* ***Stereocilia :** Immobile cilia e.g. of epididymis.*
- ***Bacterial flagellum** consists of a single fibril **flagellin protein**, so is different from that of eukaryotes.*

C. MICROTUBULES AND MICROFILAMENTS :

- ***Cytoskeleton** is formed of three types of filaments: microtubules, microfilaments and **intermediate filaments**.*
- *Microtubules of spindle fibres are **labite type**, while those of cilia and flagella are of **stable type.***
- ***Palade** (1955) : Reported microtubules in the spindle fibres.*
- ***Slautterback** (1963) : Gave the **term microtubule.***
- *Microtubules of sensory cells act as **transducers** and convert sensory stimuli into nerve impulses.*

CELL-INCLUSIONS

These are non-living structures of the cytoplasm and are also called **deutoplasmic** or **Ergastic bodies.**

A. VACUOLES

1. Occurrence. Vacuoles are found in all the eukaryotic cell types. In animal cells, there are a number of small sized vacuoles irregularly scattered in the cytoplasm while in the plant cells, there is single large **central** or **sap vacuole** filled with cell-sap. It occupies about 90% of the cell volume.

2. Structure. A vacuole is formed of **two parts :**

(a) Tonoplast. It is outer, **single-layered**, unit-membrane and semipermeable. It transports ions and other materials by active transport to store them in sap.

(b) Cell-sap. It is liquid present inside the central vacuole and is formed of water, minerals, sugars, amino acids, proteins, anthocyanins, alkaloids etc.

3. Functions

(a) Cell-sap exerts **turgor pressure** which helps in osmotic expansion of the cell and **growth**.

(b) It **stores water (maximum amount), pigments (*e.g.* anthocyanin), nutrients and minerals.**

(c) Sometimes, it also **stores wastes.**

These vacuoles are modified differently to perform different functions :

(a) Food vacuoles. These contain ingested or digested or undigested food. These have been reported in the phagocytes, protozoan etc.

(b) Contractile vacuoles. These are found in the fresh-water protozoans e.g., *Amoeba*, *Paramecium* etc. and help in **osmoregulation** and **excretion.**

(c) Gas or air vacuoles (Pseudovacuoles). These are found in **Cyanobacteria** (blue green algae) and photosynthetic bacteria and provide **buoyancy** as contain the metabolic gases.

B. RESERVE FOOD

It may be in the form of **starch grains** (e.g., in potato-tuber cells), or **glycogen granules** (e.g., in liver and muscle cells of animals), or **protein granules** (e.g., endosperm of maize seed), or **oil droplets** (e.g., in **adipocytes** of fat-bodies; endosperm cells of castor and coconut; and in cotyledons of groundnut and mustard).

C. Gases. These include O_2, CO_2, N_2 etc.

D. Wastes. These include ammonia, urea, uric acid.

E. Inorganic crystals. These include crystals of calcium salts and silica. Silica is generally found in the epidermal cells of grasses. Crystals of calcium carbonate, called **cystoliths**, are found in epidermal cells of *Mimordica* (Kerala), while crystals of calcium oxalate are called **raphides** and are found in the epidermal cells of *Eichhornia* (water hyacinth), *Asparagus*, *Lemna*, etc.

F. Secretions. Found in glandular cells and include **mucus** (goblet cells), resins, gums, etc.

Table 22. Differences between Cell-organelles and Cell-inclusions.

Characters	Cell-organelles	Cell-inclusions
1. Definition	These are **living structures** of the cytoplasm.	These are **non-living structures** of the cytoplasm.
2. Examples	ER, Golgi body, mitochondria, plastids, ribosomes, etc.	Vacuoles, reserve food, gases, wastes, etc.

PRACTICE PROBLEMS – CELL INCLUSIONS

101. What are cell inclusions?
102. Give two functions of cell sap.
103. What is the function of contractile vacuole?
104. Name the most commonly found stored food of plants and animals.
105. What are cystoliths and raphides?

ANSWERS TO PRACTICE PROBLEMS

101. Non-living cytoplasmic structures.
102. Exerts turgor pressure and stores water, minerals, wastes, etc.
103. Osmoregulation.
104. Plants = starch ; Animals = glycogen.
105. Cystoliths are crystals of calcium carbonate, while raphides are crystals of calcium oxalate.

LEARNING PLUS

- *Vacuoles are absent in bacteria and PPLO.*
- *Cells with raphides are called **idioblasts**.*
- ***Vacuole** of cells of Acacia (kikar) stores cyanides.*
- ***Secretory materials :***
  - ***Quinine** in the bark of **Cinchona**.*
  - ***Theine** in the tea leaves.*
  - ***Morphine** in the poppy fruits.*
  - ***Caffeine** in the coffee beans.*
  - ***Nicotine** in the tobacco leaves.*
  - ***Resins** and **gums** in conifers.*

IV. NUCLEUS

1. Discovery. It was first described by **Robert Brown** (1831 A.D.) in the root cells of orchid cells.

2. Definition. The nucleus, also called **director of the cell,** is the most important part of the cell which directs and controls all the cellular functions.

3. Occurrence. A true nucleus is present in all the eukaryotes except mature mammalian RBCs, sieve-tube cells of phloem, tracheids and vessels of xylem.

4. Position. The nucleus is **generally centric** but is peripheral in adipocytes (fat-cells) and basal in the columnar cells, while in most of plant cells, it is excentric due to large central vacuole.

5. Number. Mostly the cells are **monokaryotic** but may be :

Anucleate (with no nucleus) *e.g.*, RBCs of mammals; sieve tube cells of phloem.

Binucleate *e.g.*, ciliate protozoans like *Paramecium.*

Multinucleate *e.g.*, *Opalina* (a protistan protozoan) and **voluntary muscle fibres.**

Multinucleate cells are called **coenocytic** *e.g.*, fungal hyphae of *Rhizopus* and brown algal forms *e.g.*, *Vaucheria;* and **syncitials** in animals *e.g.*, epidermis of *Ascaris;* **Plasmodium** in slime moulds.

6. Shape. It varies widely **(Fig. 37)** :

Generally **spherical** *e.g.*, cuboidal germ cells, **oval** *e.g.*, columnar cells of intestine, **discoidal** *e.g.*, flat cells of endothelium, **kidney-shaped** *e.g.*, meganucleus of *Paramecium*, **horse-shoe shaped** *e.g.*, meganucleus of *Vorticella*, **bilobed** *e.g.*, acidophils, **3-lobed** *e.g.*, basophil, **multilobed** *e.g.*, neutrophils, **long and beaded moniliform** *e.g.*, *Stentor;* and **branched** *e.g.*, silk-spinning cells of *Platyphylax* **insect larva.**

7. Size. It also varies widely and depends upon :

(a) Nucleo-cytoplasmic Index.

(b) Number of chromosomes.

(c) Cell volume and metabolic activity of the cell.

8. Chemical composition of nucleus

Proteins = 80% (65% acidic, neutral and enzymatic proteins; 15% basic proteins-histones)

DNA = 12%

RNA = 5%

Lipids = 3%

Enzymes like **polymerases** are abundantly present and help in synthesis of DNA and RNA.

Minerals in traces like Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}.

9. Ultrastructure. Under the electron-microscope, the nucleus is seen to be formed of **four components** :

A. Nuclear membrane

1. Discovery. Nuclear membrane, also called **nuclear envelope** or **nucleolemma** or **karyotheca**, was first discovered by **Erclab** (1845 A.D.).

2. Structure (Fig. 39). It is a bilayered envelope. Each membrane is lipoproteinous and trilaminar. Outer membrane, called **ectokaryotheca,** is studded with ribosomes and is continuous with RER at some points. Inner membrane, called **endokaryotheca,** is without ribosomes and is internally lined by protein fibres called **fibrous** or **nuclear lamina or nuclear cortex or honey comb layer.** Two membranes are separated by a fluid-filled **perinuclear space** (about 10-50 nm).

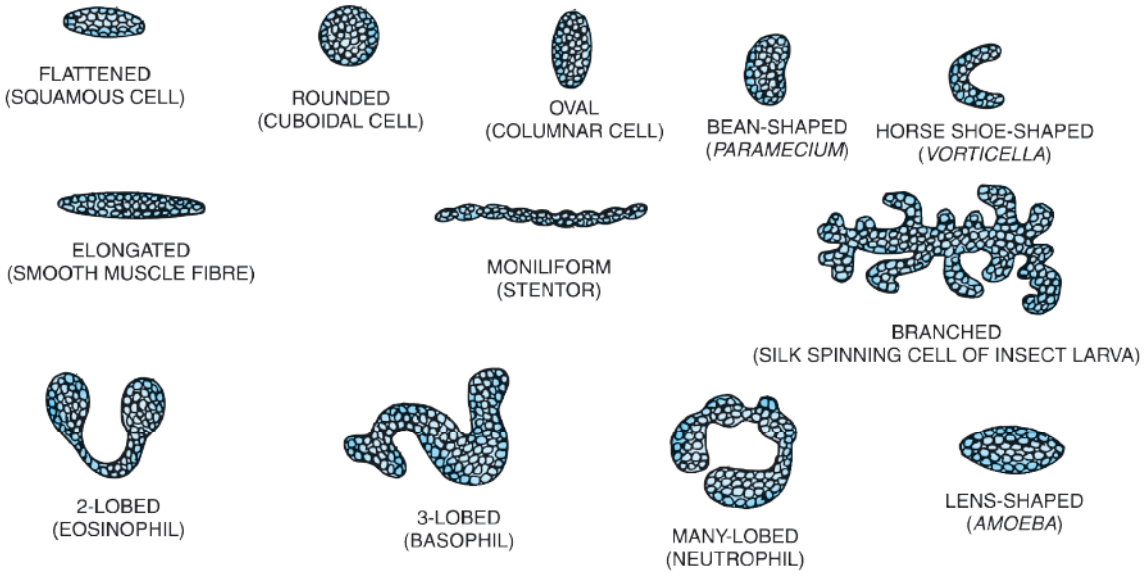


Fig. 37. Diversity in the shape of nucleus.

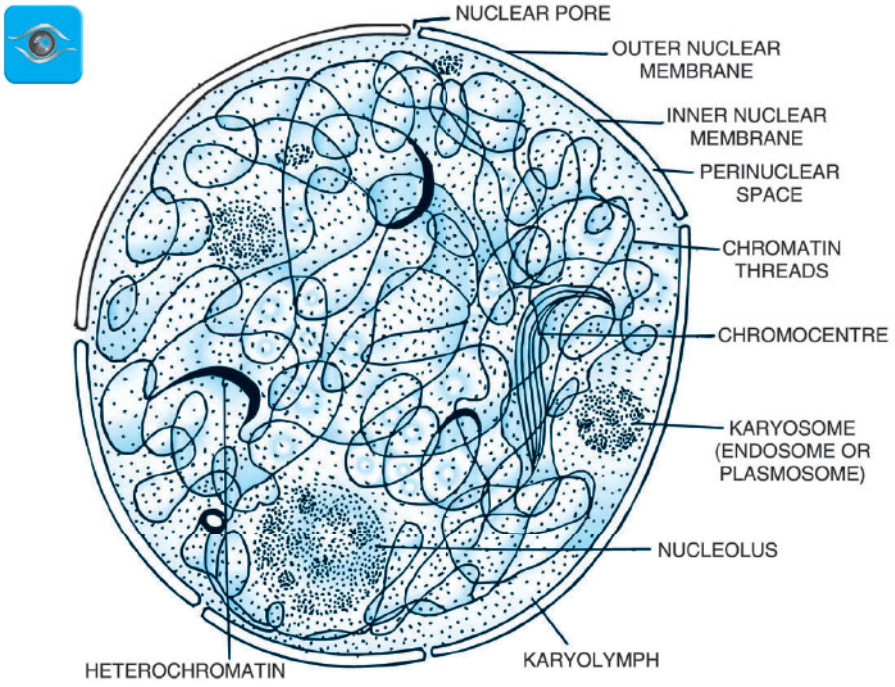


Fig. 38. Ultrastructure of a nucleus.

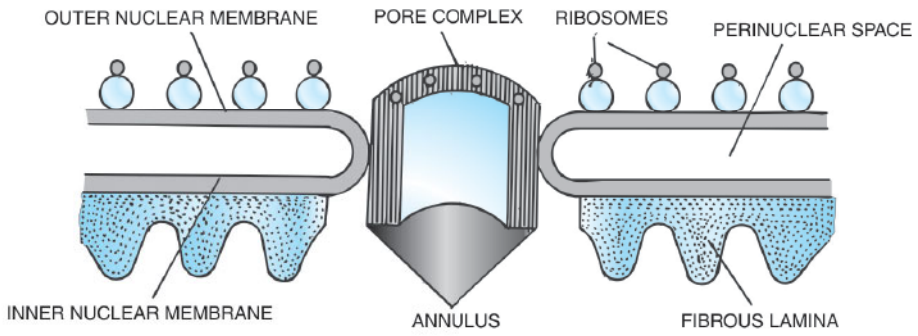


Fig. 39. V.S. of Nuclear envelope showing Nuclear pore, Ribosomes and Fibrous lamina.

Nuclear membrane is porous and has 1,000-10,000 octagonal **nuclear pores.** Each nuclear pore is about 400-1,000Å in diameter (average size is 800Å). The number and size of the nuclear pores depend upon the needs of the cell. Each nuclear pore is fitted with a cylindrical structure, called **annulus** and both collectively form the **pore complex** or **pore basket.** Annulus has 8 micro-cylinders in its wall. It also encloses a **channel** having **nucleoplasmin** for the movement of substances. Annulus acts as a diaphragm and regulates the size of the nuclear pore.

3. Origin. It is formed by the **fusion of ER elements** during the telophase of cell division.

4. Functions

(a) It regulates the **nucleo-cytoplasmic interactions.**

(b) It allows the **passage of inorganic ions** and small organic molecules.

(c) It helps in **pinocytosis** and **phagocytosis**.

(d) It allows passage of ribosomal subunits, RNAs and proteins through nuclear pores.

(e) Fibrous lamina helps in **dissolution and reformation** of nuclear membrane during cell division.

B. Nucleoplasm (Nuclear sap or Karyolymph or Karyoplasm)

1. Structure. It is transparent, homogenous, semifluid, colloidal ground substance present inside the nuclear membrane. It is chemically formed of water, sugars, minerals, nucleotides, ribosomes, enzymes (DNA polymerase and RNA polymerase), mRNA and tRNA molecules.

2. Functions

(a) It acts as **nuclear skeleton** and helps in maintaining the **shape** of nucleus.

(b) It helps in the **formation of spindle proteins.**

(c) It is the seat of **synthesis of NAD, ATP, DNA, RNAs** and **ribosomal subunits.**

(d) It supports nuclear chromatin and nucleoli.

C. Nucleolus

1. Discovery. Nucleolus was first observed by **Fontana** (1781 A.D.) in the skin cells of an eel. Term '**nucleolus**' was coined by **Bowman** (1840 A.D.). Its light microscopic structure was given by **Wagner** (1840 A.D.).

2. Position. It is associated with **nucleolar organizer region** (NOR) of the chromosome. It is absent in muscle fibres, RBC, yeast, sperm and prokaryotes.

3. Number. Generally, a diploid cell is with two nucleoli but there are five nucleoli in a somatic cell of man and about 1000 nucleoli in the oocytes of *Xenopus*. These are larger in size and more in number in the cells that are actively involved in protein synthesis.

4. Structure (Fig. 40). A nucleolus is a darkly stained granular **naked organelle** with **no limiting membrane.** It is formed of **four parts :**

Central and proteinous part called **pars amorpha, fibrillar zone** and **granular zone** of ribonucleoproteinaceous fibrils and granules which collectively form **nucleonema** and outer **nucleolar-associated chromatin** of nucleolar DNA and is again differentiated into **perinucleolar** and **intranucleolar chromatin.**

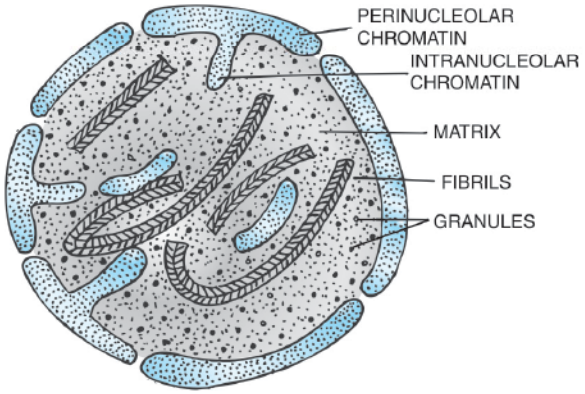


Fig. 40. Ultrastructure of a Nucleolus.

5. Chemical composition. Nucleolus is mainly formed of nucleolar-RNA (20%), non-histone acidic proteins (70-80%) and DNA (7-10%). It is a **storehouse** of r-RNA.

6. Origin. By **nucleolar DNA** of the NOR.

7. Functions

(a) It is seat of **biogenesis of r-RNA** and also **stores r-RNA,** so it is called **ribosome factory**.

(b) It plays important role in **spindle formation** during **cell division**.

(c) Also controls **nuclear-cytoplasmic transport** of r-RNA, m-RNA and t-RNA.

D. Nuclear Chromatin (Nuclear Reticulum)

1. Structure. It is a darkly stained (Gr. *chroma* = colour) network of long and fine threads, called **chromatin fibres.** It is stained by a basic fuchsin **Feulgen stain.** It was first reported by **W. Flemming** (1882 A.D.). During interphase, the chromatin is differentiated into **two parts :**

(a) Heterochromatin. It is formed of thick regions and are more darkly stained than other areas. It is with condensed DNA which is **transcriptionally inactive** and **late replicating.**

(b) Euchromatin. It is **true chromatin** and is formed of thin and less darkly stained areas. It is with loose DNA which is **transcriptionally active and early replicating.**

The chromatin fibres are chemically formed of DNA, RNA and proteins (histones and non-histone proteins). During cell-division, these chromatin fibres condense by spiralization and dehydration into a number of rods, called **chromosomes** (**Hofmeister,** 1848 A.D.). Term 'chromosome' was given by **Waldayer** (1888 A.D.). Number of chromosomes is species specific e.g., 2 in *Ascaris*, 8 in *Drosophila* (fruit fly), 26 in frog, 46 in man and 48 in apes. Smallest number of chromosomes is found in *Ascaris megalocephala* (2N = 2) while largest number of chromosomes is found in a radiolarian protozoan - *Aulocantha* (2N = 1600).

A chromosome **(Fig. 41)** consists of two identical and spirally coiled threads, called **sister chromatids,** joined at lightly coloured constriction, called **centromere** or **primary constriction.** Each centromere has two disc-shaped structures called **kinetochores** which are sites of attachment of spindle fibres during cell division. On the basis of number of centromeres, the chromosomes are called **monocentric** (most common type) or **dicentric** (e.g., maize) or **polycentric** (*Parascaris equorum*) or **acentric** (with no centromere). Position of centromere varies and on this basis, chromosomes are of **four types:**

Table 23. Differences between Cytoplasm and Nucleoplasm.

Characters	Cytoplasm	Nucleoplasm
1. Position	Between the cell-membrane and the nucleus.	Inside the nucleus.
2. Nature of structures	Various types of cell-organelles present	Only nucleoli and chromatin fibres. and cell-inclusions.
3. Functions	It helps in glycolysis, biosynthesis of proteins and exchange of materials between the cell-organelles.	It helps in the formation of spindle proteins during cell division and acts as nuclear skeleton.
4. Cyclosis	Cyclosis occurs.	Cyclosis does not occur.

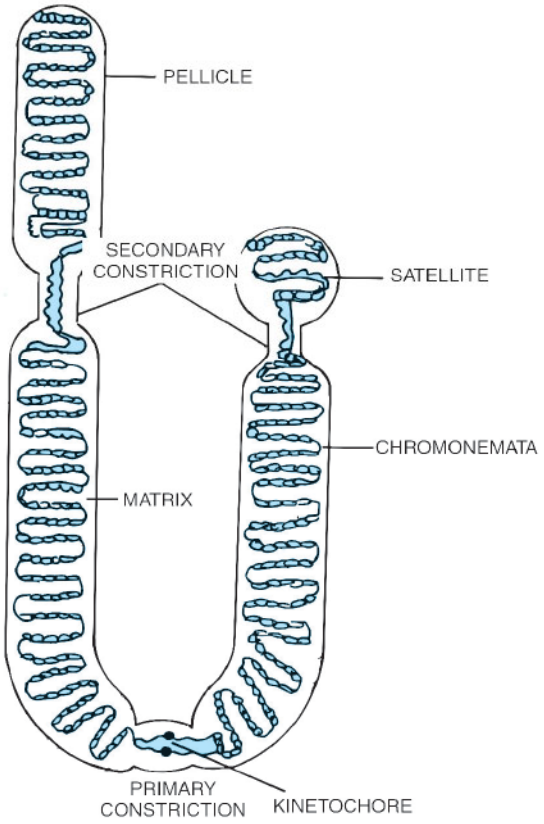


Fig. 41. A metaphase chromosome.

Centromere may be terminal (**Telocentric with only one arm**) or subterminal (**Acrocentric with two highly unequal arms**) or near the centre (**Sub-metacentric with two slightly unequal arms**) or at the centre (**Metacentric with two equal arms**) of chromosome (**Fig. 42A**). Each chromatid is formed of 2 or 4 or 8 threads called **chromonemata.** Each chromonemata is a protein-coated DNA and is about 100Å in diameter. Some chromosomes have additional non-staining subterminal constriction, called **secondary constriction** and such chromosomes are called **SAT-chromosomes.** In human karyotype, there are five pairs of SAT-chromosomes (13, 14, 15, 21 and 22 pairs). Certain secondary constrictions are involved in the formation of nucleoli and are called **nucleolar organising regions (NORs)** and such chromosomes are called **nucleolar chromosomes.**

Electron microscopic studies showed that a chromatin fibre is formed of a chain of repeated units called **nucleosomes (Fig. 42B)**. Each nucleosome is formed of a core complex called ***nu* body** wrapped by DNA strand (of 166 to 200 base pairs). Core complex is formed of a **histone octomer** of four types of histone molecules (2 molecules each) — **H_2A, H_2B, H_3 and H_4.** The DNA segment between the adjoining nucleosomes is called **linker DNA.** (of 60 base pairs). H_1 helps in grouping of nucleosomes and is not passed to next generation.

2. Functions

(a) Chromatin fibres contain DNA which acts as **genetic material.**

(b) These control the **synthesis of structural as well as enzymatic proteins.**

(c) The changes in DNA produce **variations.**

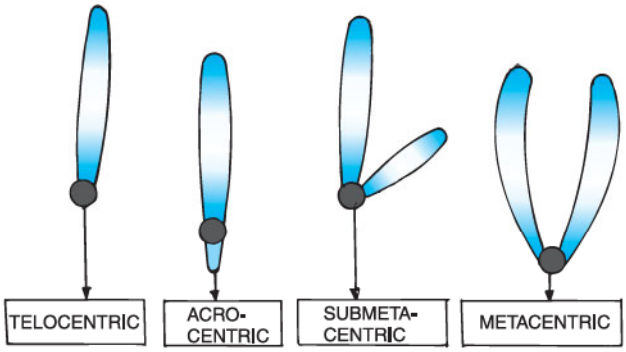


Fig. 42A. Types of chromosomes.

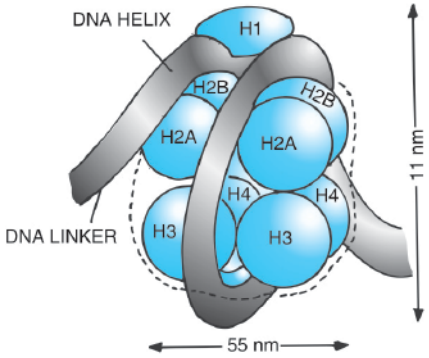


Fig. 42B. Structure of a nucleosome.

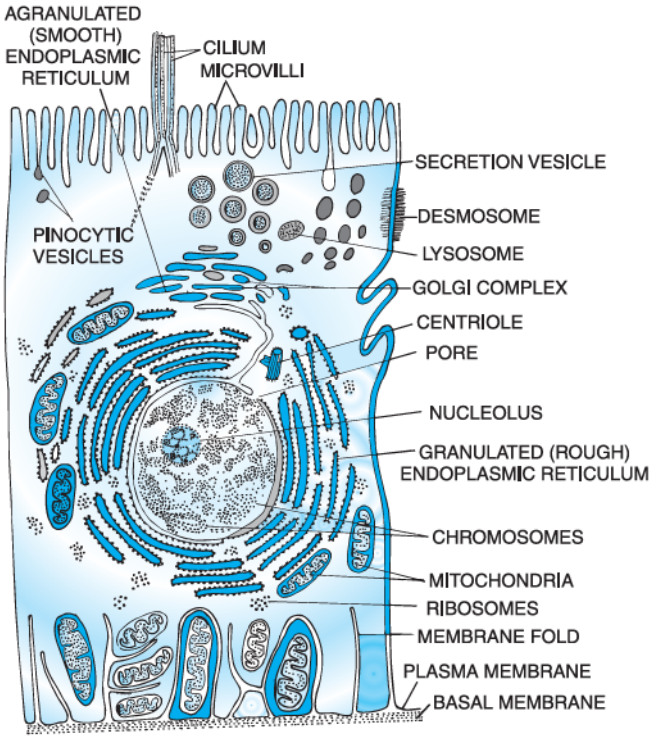


Fig. 43. Ultrastructure of an animal cell.

Table 24. Differences between Chromatin and Chromosomes.

Chromatin	Chromosomes
1. It is **uncondensed part** of nucleoprotein complex.	1. Chromosomes are **condensed parts** of the nucleoprotein complex.
2. Chromatin is observable in the **interphase nucleus.**	2. Chromosomes are observable during **M-phase or nuclear division.**
3. It is active in **controlling metabolism** and other **activities of the cell.**	3. Chromosomes are mainly meant for **distribution of genetic informations** to the daughter cells.

Table 25. Differences between Heterochromatin and Euchromatin.

Characters	Heterochromatin	Euchromatin
1. **Amount of stain**	Darkly stained.	Lightly stained.
2. **Chromatin**	Condensed regions of chromatin fibres.	Less tightly coiled regions of chromatin fibres.
3. **Transcription**	Transcriptionally inactive.	Transcriptionally active.
4. **Effect of environmental factors**	Less affected by temperature, sex or age.	More affected by temperature, sex or age.
5. **Frequency of crossing over**	Low.	High.
6. **Replication**	Late replicating.	Early replicating.

Table 26. Composition and functions of Eukaryotic Cellular Structures.

Name	Composition	Functions
Cell wall	Contains cellulose fibrils.	Support and protection.
Plasma membrane	Bilayer of phospholipid with embedded proteins.	Selective passage of molecules into and out of cell.
Nucleus	Nuclear envelope surrounding the nucleoplasm, chromatin and nucleoli.	Control of growth and reproduction.
Nucleolus	Concentrated area of chromatin, RNA and proteins.	Ribosomal formation.
Ribosomes (polysomes)	Protein and RNA in 2 subunits.	Protein synthesis.
Endoplasmic reticulum	Membranous flattened channels and tubular canals.	Synthesis and/or modification of proteins and other substances, and transport by vesicle formation.
Rough ER	Studded with ribosomes.	Protein synthesis.
Smooth ER	Having no ribosomes.	Lipid synthesis.
Golgi apparatus (dictyosome)	Stack of membranous saccules.	Processing and packaging of molecules (e.g., glycoproteins).
Vacuoles and vesicles	Membranous sacs.	Storage of substances.
Lysosomes	Membranous vesicles containing digestive enzymes.	Intracellular digestion.
Microbodies	Membranous vesicles containing specific enzymes.	Various metabolic tasks.
Mitochondria	Inner membrane (cristae) within outer membrane.	Cellular respiration.
Chloroplasts	Inner membrane (grana) within 2 outer membranes.	Photosynthesis.
Cytoskeleton	Microtubules and microfilaments.	Shape of cell and movements of its parts.
Cilia and flagella	9 + 2 pattern of microtubules.	Movement of cell.
Centrioles	9 + 0 pattern of microtubules	Form basal bodies which give rise to microtubules.

FUNCTIONS OF NUCLEUS

1. It controls the **synthesis of structural proteins.**
2. It controls the **cellular functions** by controlling the **synthesis of enzymatic proteins.**
3. It contains the **genetic informations.**
4. It takes part in the **formation of ribosomes.**
5. It induces genetic **variations** which help in **organic evolution.**
6. It controls **cellular-differentiation** by regulating differential gene expression.

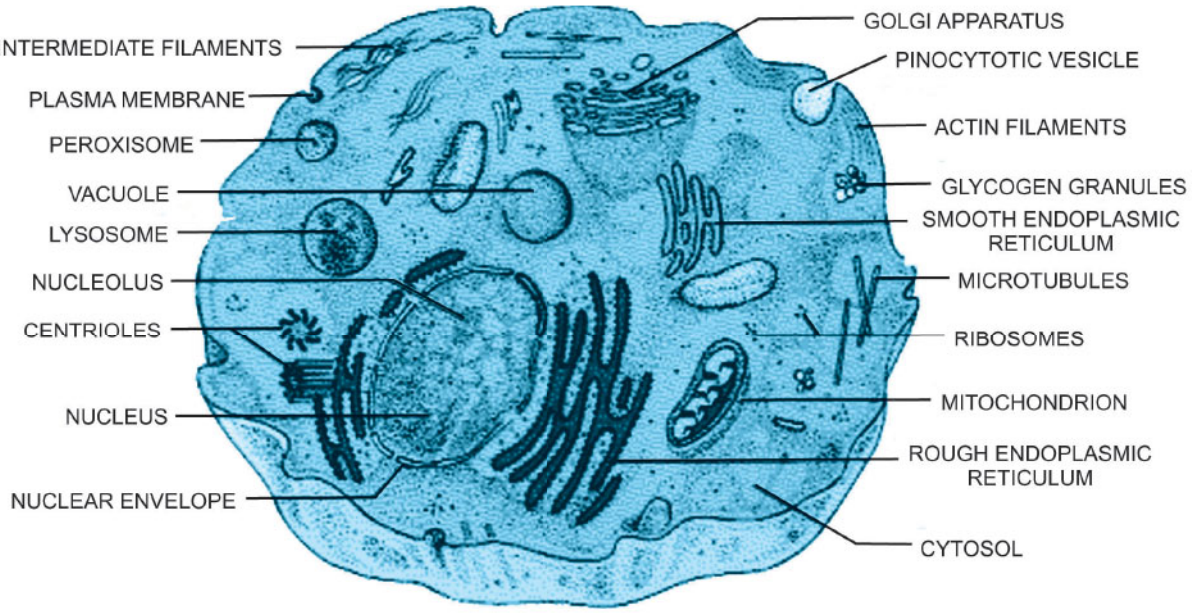


Fig. 44A. ANIMAL CELL (Electron Microscopic Structure).

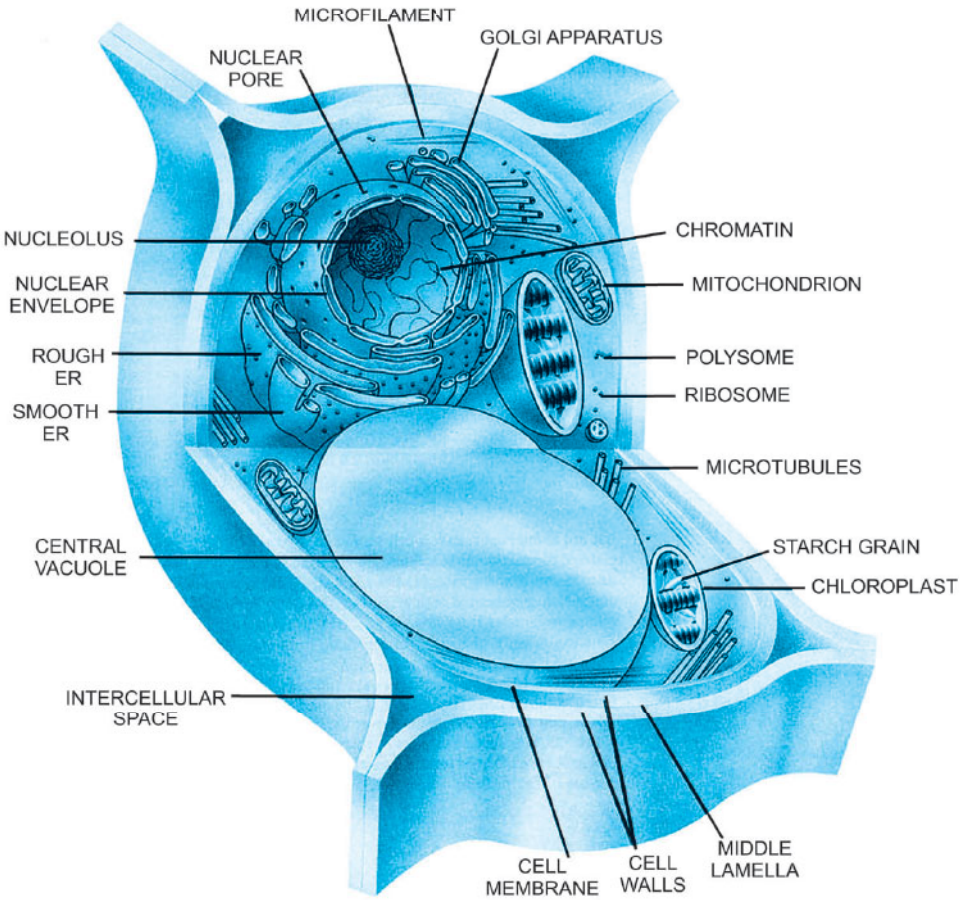


Fig. 44B. PLANT CELL (Electron Microscopic Structure).

Table 27. Differences between Plant cell and Animal cell.

Characters	Plant cell	Animal cell
1. Cell wall	A plant cell consists of cellulose **cell wall** surrounding the plasma membrane.	The cell wall is absent. The limiting membrane of the cell is **plasma membrane**.
2. Plastids	A plant cell consists of **plastids** in general.	In an animal cell, the plastids in general are absent.
3. Vacuole	It consists of **single large central vacuole**.	Vacuoles are absent or a few small sized.
4. Centriole	Centriole is absent.	**Centriole** is present though absent in invertebrates.
5. Nucleus	Its nucleus is often pushed to one side in the peripheral cytoplasm by sap vacuole.	Its nucleus is generally near the centre.
6. Mitochondria	Mitochondria are usually fewer.	Mitochondria are generally numerous.
7. Cristae	Cristae of mitochondria are tubular.	Cristae of mitochondria are plate-like.
8. Crystals	Crystals may be present.	Crystals are usually absent.
9. Division	Cytoplasm, during cell division usually divides by **cell plate** method.	Cytoplasm divides by **furrowing** or cleavage method.
10. Effect of hypotonic solution	Cells do not burst due to the presence of cell wall.	Animal cells burst due to absence of cell wall.
11. Synthesis	Plant cells are capable of forming all the amino acids, coenzymes and vitamins.	Animal cells cannot form all the amino acids, coenzymes and vitamins.
12. Spindle	**Anastral.**	**Amphiastral.**

COMPETITION PLUS

SPECIAL TYPES OF CHROMOSOMES

(A) LAMPBRUSH CHROMOSOME

Discovery and occurrence. Lampbrush chromosomes were first discovered by **Ruckert** (1882) in the oocytic nuclei of *Salamandra*. Now these are found in the diplotene stage of prophase–I in the **primary oocytes** of vertebrate groups having yolky eggs (e.g. amphibians, reptiles and birds) and some invertebrates (e.g. insects).

Size. These are **largest-sized** chromosome, so called **giant chromosomes** e.g. lampbrush chromosomes of oocytic nuclei of *Salamandra* are as long as 5900 µm (5.9 mm). So these are even visible with naked eye.

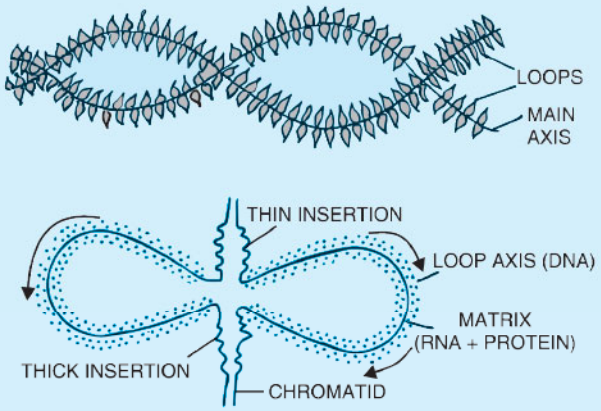


Fig. 45. Lampbrush chromosome :
A. A bivalent. **B.** A pair of lateral loops.

Structure (Fig. 45). Each chromosome is formed of a main **central axis** and several pairs of **lateral loops** giving the appearance of a brush, so called **lampbrush chromosome.** Central axis is made of DNA and proteins. Chromosomal axis bears a series of darkly stained granules, called **chromomeres,** and are transcriptionally inactive.

Lateral loops arise in pairs. Each loop is formed of DNA core which is surrounded by a **matrix** formed of RNAs and proteins, and are transcriptionally active. Each lateral loop represents one transcription unit.

The **Master-slave gene hypothesis** states that a chromomere acts as a master gene while loops correspond to slave genes.

(B) POLYTENE CHROMOSOME

Discovery and occurrence. Polytene chromosomes were first discovered by **Balbiani** (1881) in **midgut larva** of a dipteran insect (*Chironomous*). Later these were found in the cells of **salivary glands,** of the larvae of dipteran insects e.g. *Drosophila,* mosquitoes, etc. so also called **salivary gland chromosomes.** Later these were also reported in suspensor cells of embryo and antipodal cells of empryo sac.

Size. These are **second largest-sized chromosomes.** These are about 200 µm or more in length (normal chromosome is about 7.5 µm. So these are called **giant chromosomes.**

Structural properties (Fig. 46)

1. These are **multi-stranded or polytenic** chromosomes and may be formed of as many as 512 to 1024 chromatids. It is due to a process called **endomitosis.**

2. Homologous chromosomes show **somatic synapsis** (paired even in somatic cells).

3. Centromeres of all the chromosomes and their heterochromatic regions are fused to form a darkly stained **chromocentre.**

4. Each chromosome is with a specific pattern of dark-coloured **bands** and alternatively arranged light-coloured **interbands. Lefevre** (1974) suggested the bands as the sites of genes and proposed **one band – one gene hypothesis**. The banding pattern is a **species-specific character.**

5. One or more bands give rise to swellings called **puffs or bulbs.** Each puff is formed of a core of DNA covered by a matrix of RNA which shows that these puffs are the sites of transcription.

6. Some chromonemata give rise to a number of large-sized loops, called **Balbiani rings.**

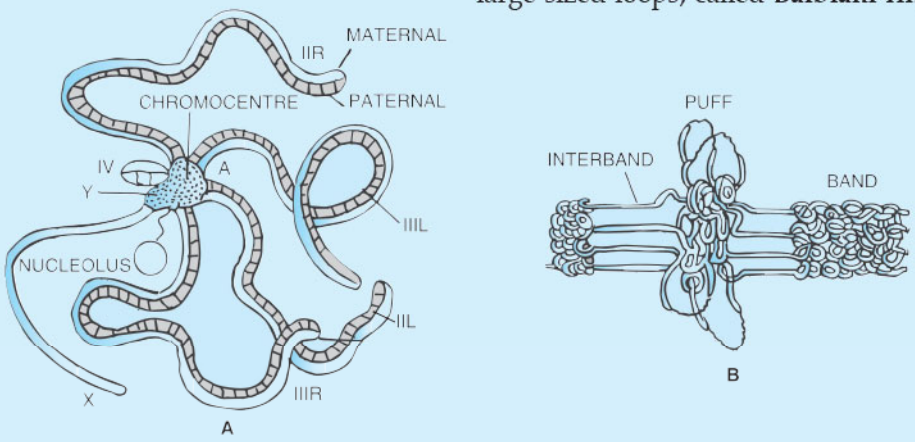


Fig. 46. Polytene chromosome : **A.** Somatic synapsis of chromosomes; **B.** Puffs arising from bands.

R U CURIOUS

- **J. Hammerling (1934)** experimentally proved that genetic informations lie in the nucleus of *Acetabularia* (a green alga).
- **Nuclear pores** form about 10% of surface area of nuclear membrane.
- In nucleus, DNA (12%) and histones (15%) ratio is nearly 1 :1.
- Nucleolus is also called **little nucleus** or **Brain of the nucleus.**
- Nucleolus is the largest structure of the nucleus and forms about 25% of the nuclear volume.
- **De Robertis** *et. al.* **:** (1971) : Gave ultrastructure of nucleus.
- **Nucleosomes** are called functional units of chromonema.
- **Barr body** found in the normal somatic cells of human female is a heterochromatized (or Heteropyknotic) X-chromosome.
- Shorter arm of a submetacentric chromosome is called **p-arm** while its longer arm is called **q-arm.**
- A single human cell has about 6 billion nucleotide pairs constituting 2 meter long thread of DNA present in 23 pairs of chromosomes.

PRACTICE PROBLEMS – NUCLEUS

106. Who discovered nucleus?
107. Why is nucleus called director of the cell?
108. Give the nature of nucleus in the prokaryotic cells.
109. What do you mean by syncytial nature of cell?
110. Name four components of the nucleus.
111. What is nuclear-pore complex?
112. How does outer nuclear membrane differ from inner nuclear membrane?
113. Give two functions of nuclear membrane.
114. List two functions of nucleoplasm.
115. What is nucleolar-organizer region (NOR)?
116. Name two cellular structures which have no limiting membrane.
117. List two functions of nucleolus.
118. Who coined the term chromosome?
119. Give one major difference between heterochromatin and euchromatin.
120. What are SAT - chromosomes?
121. Define nucleosome.
122. Name four types of chromosomes on the basis of position of centromere.

ANSWERS TO PRACTICE PROBLEMS

106. Robert Brown (1831).
107. Because it directs and controls all the cellular functions.
108. Incipient nucleus with no nuclear membrane, called **nucleoid.**
109. When a cell is multinucleated e.g. a fungal hypha of *Rhizopus.*
110. Nuclear membrane, nucleoplasm, nucleolus and nuclear chromatin.
111. A nuclear pore with its annular diaphragm is called nuclear pore complex.
112. Outer membrane is continuous with RER and is studded with ribosomes, while inner membrane is smooth and is lined by dense fibrous lamina.
113. Regulates nucleo-cytoplasmic interactions and forms cisternae of ER.
114. Acts as nuclear skeleton and formation of spindle proteins.
115. It is secondary constriction whose DNA forms nucleolus.
116. Nucleolus and ribosomes.
117. Helps in biogenesis of r-RNA and spindle formation.
118. Waldayer (1888).
119. Heterochromatin is darkly stained, condensed and transcriptionally inactive, while euchromatin is lightly stained, loose and transcriptionally active DNA.
120. Chromosomes having secondary constriction and satellites.
121. Darkly stained DNA-histone octameric complexes present on a chromatin fibre.
122. Telocentric, acrocentric, submetacentric and metacentric.

ADDITIONAL USEFUL INFORMATIONS ABOUT NUCLEUS FOR COMPETITIVE EXAMINATIONS

- ***Hammerling*** *(1953) : Conducted grafting experiments on* ***Acetabularia*** *and demonstrated that nucleus is a storehouse of genetic informations.*
- *In young cell, nucleus occupies* ***25%*** *of cell volume while in mature cell nucleus occupies* ***10%*** *of cell volume.*
- ***Nucleo-cytoplasmic index or Karyoplasmic index :*** *Ratio between the volume of nucleus and volume of cytoplasm.*
- *Nucleus of polyploid cells is larger than that of diploid cells which in turn is larger than that of haploid cells of that species.*
- ***Heterochromatin of 2 types :***
  - ***Facultative heterochromatin :*** *Temporarily inactivated chromatin and forms 2.5% of the genome.*
  - ***Constitutive heterochromatin :*** *Permanently inactivated chromatin and generally found near centromeres, telomeres, near NORs etc.*
- ***Strasburger :*** *Proposed* ***Law of constant chromosome number.***
- ***Outdet*** *(1975) : coined the term* ***nucleosome.***
- ***B-chromosomes or supernumerary chromosomes :*** *Small sized, heterochromatic and genetically unnecessary extra chromosomes.*
- ***m-chromosomes :*** *Minute sized (less than 0.5 μm) chromosomes found in many bryophytes and insects.*
- *H_1, H_{2A} and H_{2B} proteins are* ***lysine rich*** *(H_1 is* ***very lysine rich****) while H_3 and H_4 are* ***arginine rich*** *polypeptide chains.*
- ***Finch and Klug*** *(1976) : Proposed* ***solenoid model.*** *It states that DNA is associated with histone proteins to form a series of beads called* ***nucleosomes.***
- ***Acentric chromosome :*** *Chromosomes with no centromere. Lost in cell division.*
- *Chromosomes are stained by basis stain* ***acetocarmine*** *or* ***acid fuchsin.***

CHAPTER SUMMARY

- **Cell** is the structural and functional unit of organisms which may be unicellular or multicellular. It was first discovered by **Robert Hooke (1665)** while cell theory was proposed by **Schleiden and Schwann (1839)** which was considered as fundamental generalisation of biology of 19th century. Cell theory proposed that new cells are formed *de novo*. It was objected by **Rudolf Virchow** who proposed **theory of cell lineage** based on *omne cellula e cellula.* So cell theory was modified as **cell principle.**
- A cell is formed of **three functional regions :** Plasma membrane, cytoplasm with cell organelles and cell inclusions, and nucleus. On the basis of nature of nucleus, cells are of **two types: Prokaryotic** and **Eukaryotic cells.**
- **Cells show diversity** in their shape, size, number, life span and functions. Cellular shape depends upon function to be performed. Cellular size varies not only in different organisms but also in different cell types of same organism. Cell size depends upon surface area to volume ratio, nucleo-cytoplasmic ratio and metabolic rate of the cell. Small bodied organisms have more surface area per unit volume than large bodied. Organisms are either unicellular or multicellular.

- **Prokaryotic cellular nature** is found in members of kingdom Monera e.g. bacteria, cyanobacteria, archaebacteria, mycoplasma etc. On the basis of shape, bacteria are of 4 types. Cocci , bacilli, spirillum and vibrio. Basically, a bacterial cell is formed of 3 parts : cell envelope, nucleoid and cytoplasm. Cell envelope is formed of 3 parts: Outer **glycocalyx,** middle **cell wall** of peptidoglycan (or murein) and inner **plasma membrane** which is infolded to form **mesosomes** in Gram + ve bacteria. On the basis of staining ability of cell wall, bacteria are of two types: **Gram positive** and **Gram negative** bacteria. **Cytoplasm** has 70 S ribosomes, reserve food and inclusion bodies but lacks membrane-bounded cell organelles **Nucleoid** is formed of single, circular, naked and dsDNA only. Some bacteria have special structures like:
  - Extra-nuclear rings of DNA called **plasmids.**
  - One or more **flagella** formed of single fibril of **flagellin protein.**
  - Longer and broader tubular structures, called **pili**, to help in adhesion.
  - Minute and hair-like **pili** to help in conjugation.
- Eukaryotic cells are found in members of Kingdom Protista, Fungi, Plantae and Animalia. Basically, a eukaryotic cell is formed of plasma membrane, cytoplasm and true nucleus. Plasma membrane is lipoproteinous and trilaminar. It was called **unit membrane** by **J. Robertson** while its most accepted structural model called **"fluid mosaic model"** was proposed by **Singer and Nicholson**. Chemically, plasma membrane is formed of lipids (about 40%), proteins (50-60%) and carbohydrates (1-5%). Main lipids found are phospholipids (e.g. lecithin, cephalin, etc.). while proteins are of 2 types: extrinsic and intrinsic proteins.
- Plasma membrane is a **semipermeable** or **selectively permeable membrane** and regulates exchange of materials between cytoplasm and ECF. Two mechanisms are involved: **Passive** and **Active transport.** In passive transport, the materials move along concentration gradient and do not utilize energy. Passive transport involves: **diffusion** (e.g. exchange of gases at alveoli of the lungs); **facilitated diffusion** (i.e. diffusion in the presence of carrier protein molecules) and **osmosis** (i.e. flow of water or any solvent from higher water potential to lower water potential). **Plasmolysis** of plant cells in hypertonic solution occurs by exosmosis but is a reversible phenomenon. Active processes operates against concentration gradient and involves usage of energy provided by ATP. Movement of microbiomolecules occurs by **active transport;** while that of macrobiomolecules occurs by **emiocytosis** (when expelled outside the cells) or **endocytosis** (when taken inside the cells).
- **Cell wall** is present outside cell membrane in all the plant cells, bacteria, cyanobacteria, fungi and some protists. In plant cells, it is formed of primary cell wall of cellulose, hemicellulose and pectin, and secondary cell wall of cellulose microfibrils further strengthened by suberin or liginin or cutin. Middle lamella of calcium and magnesium pectates lies between cell walls of adjoining plant cells. Cell wall is protective and supportive in function.
- **Cytoplasm** of eukayotic cells shows streaming movements called **cyclosis**. It is formed of cytoplasmic matrix and a number of cytoplasmic structures like **cell organelles** and **cell inclusions**.
- **Cell organelles** are living cytoplasmic sub-cellular structures like ER, Golgi complex, ribosomes, mitochondria, lysosomes, plastids, centrioles, etc. ER, Golgi complex, lysosomes, peroxisomes and vacuoles form an **endomembrane system** as their functions are coordinated.
- **Endoplasmic reticulum** was discovered by **Porter** *et.al*. It is a well developed network of interconnected cisternae, tubules and vesicles throughout the cytoplasm of cell. It is of 2 types: **SER** (without ribosomes) and **RER** (with ribosomes). ER helps in cell circulatory system, a part of cytoskeleton, storage, cell plate and nuclear membrane formation,lipid synthesis (SER), protein synthesis (RER), etc.
- **Golgi complex** was discovered by **Camillo Golgi.** It is formed of flat and curved cisternae, vacuoles and vesicles. It has two specific faces: *Cis* (formative) and *trans* (maturation) face. It is involved in cellular secretion, condensation of secretion, cell plate formation, acrosome formation and glycosylation of lipids and proteins.
- **Lysosomes.** These were discovered by **de Duve** (1955) and are electron microscopic, vesicullar structures having acid hydrolases (with pH5) which help in heterophagy, autophagy, autolysis, extracellular digestion, seed germination, scavenging, defence, etc. These show **polymorphism.**
- **Ribosomes.** These were discovered by **Palade** and are electron microscopic, naked, ribonucleoprotein particles attached on RER or lying freely in the cytoplasm. These are of 70 S type(50 S and 30 S subunits) in prokaryotes and of 80 S type (60 S + 40 S subunits) in eukaryotes. These are sites of protein synthesis so are called **protein factories**.
- **Mictochondria** were first discovered by **Kolliker** (1880) and show great variations in shape, size and number. It is formed of two mitochondrial membranes (forming a thermos bottle-like structure) and two chambers. Inner mitochondrial membrane is infolded to form **cristae** which are studied with **oxysomes**. Inner chamber is filled with matrix which has 70 S ribosomes, enzymes of Kreb's cycle, rings of DNA molecules, etc. Mitochondria are of **semiautonomous nature**. These act as **power houses** (as are sites of ATP synthesis).
- **Plastids** are found in all the plant cells and some protisits. These are of 2 types. **Leucoplasts** (colourless and food storage) and **chromoplasts** (with coloured pigments). Most common type of plastids are **chloroplasts**. These vary in shape, size and number. A chloroplast has two limiting membranes, ground substance stroma or matrix and grana. Stroma is with 70 S rirbosomes, enzymes for CO_2 fixation and protein synthesis, naked and circular DNA molecules, etc. Each granum is formed of superimposed **thylakoids** which contain photosynthetic units called **quantasomes.** Light phase of photosynthesis occurs in quantasomes of the thylakoids, while dark phase of photosynthesis occurs in stroma of chloroplast and involves CO_2 fixation. Chloroplasts are also **semiautonomous** in nature. Chloroplasts are sites of photosynthesis so are called **kitchens of the cell.**
- **Centrioles** were discovered by **Van Benden.** It is light microscopic microtubular structure formed of 9 microtubules in **9 + 0 arrangement.** Each microtubule is **triplet** in nature. Inside each centriole, there are a number of cartwheel

like **intracentriolar structures** while there are two **pericentriollar structures** around each centriole. Centrioles form asters (for cell division) and basal bodies.

- **Basal bodies** differ from centrioles in being ectoplasmic in position, larger in size, without intracentriollar structures but have root-like **rhizoplasts**. These give rise to cilia and flagella so help in movements and locomotion.
- **Cilia and flagella** have similar ultrastructure. Each is formed of 11 microtubules with **9 + 2 arrangement.** Each peripheral microtubule is doublet and are interlinked by interdoublet linkers. Both help in locomotion and nutrition.
- **Cytoskeleton** is formed of microtubules, microfilaments and intermediate filaments. A **microtubule** is hollow and cylindrical structure formed of spirally-arranged 13 rows of ∝, **β-dimeric tubulin protein**. Microtubules form astral rays and spindle fibres which help in cell division. **Microfilaments** are solid and contractile structures which are present in myofilaments of muscle fibres and also in microvilli of intestinal cells.
- **Microbodies** are single membrane-bound spherical EM cellular structures like **peroxisomes** (with enzymes for formation and degrading of H_2O_2 e.g. oxidase and catalse enzymes); **glyoxisomes** (involved in β-oxidation of fats and gluconeogenesis) and **sphaerosomes** (involved in formation and storage of fats).
- **Cell inclusions** are non-living cytoplasmic structures. These include: **Vacuoles,** reserve food, inorganic crystals, gases, wastes, etc. A **vacuole** is formed of central fluidy **cell sap** bounded by a single biomembrane called **tonoplast.** It stores water, wastes and exerts turgor pressure to help in growth of cells. **Contractile Vacuoles** are found in fresh-water protozoans and help in osmoregulation; **gas vacuoles** are found in cytoplasm of cyanobacteria and help in **buoyancy** of the cells. **Reserve food** is either in the form of **starch grains** or protein granules or oil droplets. Crystal of calcium carbonates are called **cystoliths** while crystals of calcium oxalates are called **raphides.**
- **Nucleus** was discovered by **Robert Brown** (1831) and is commonly called "**director of the cell**". A cell generally has a single, spherical and centric nucleus. It is formed of four components:

  ✦ **Nuclear membrane** is double membranous and helps in nuclear cytoplasmic interaction. It is porous (with nuclear pores lined with cylindrical structures). Outer membrane is studded with ribosomes.

  ✦ **Nucleoplasm** is colloidal ground substance which is seat of biosynthesis of DNA, RNAs, ribosomal subunits, etc. It also supports nuclear chromatin and nucleoli.

  ✦ **Nucleolus** is darkly stained and naked structure. It is seat of biogenesis and storage of r-RNA.

  ✦ **Nuclear chromation** is formed a netowork of darkly stained threads, called **chromatin fibres,** which during cell division undergo condensation to form thick rods called **chromosomes**. Each chromosome is formed of two identical sister chromotids joined at centromere. Chromosomes are of 4 types on the basis of position of centromere and shape e.g. **Telocentric** (Terminal centromere and rod-shaped). **Acrocentric** (sub-terminal centromere and J or L-shaped), **submetacentric** (centromere near the centre and J or L-shaped) and **metacentric** (centromere at centre of chromosome and is V-shaped).

  A chromation fibre is with knob-like repeated units called **nucleosomes**.Each nucleosome is formed of a core complex, called **nu-body,** formed of a histone octamere wrapped by DNA strand of about 200 base pairs while adjacent nucleosomes are joined by **linker DNA** of about 60 base pairs.

KEY TERMS

Active transport	:	Transport of microbiomolecules across a biomembrane in the presence of energy.
Amphipathic	:	Molecules with hydrophobic and hydrophilic ends e.g. phospholipids.
Autolysis	:	Self digestion of cell after its death.
Autophagy	:	Digestion of reserve food or certain cell organelles.
Cell biology	:	Study of structure, composition, functions and life processes of the cell.
Cell coat (Glycocalyx)	:	A protective layer of oligosaccharides present outer to plasma membrane of many animal cells.
Cell inclusions	:	Non-living cytoplasmic structures.
Cell organelles	:	Living structures of cytoplasm.
Centromere	:	Region of chromosome at which spindle fibril is attached during cell division.
Chromoplast	:	Pigmented plastid.
Cristae	:	Folds of inner mitochondrial membrane.
Cutinisation	:	Deposition of cutin in the secondary cell wall.
Cyclosis	:	Streaming movement of cytoplasm.
Desmosomes	:	Intercellular junctional complexes which help in mechanical support and cellular adhesion.
Diffusion	:	Movement of materials from higher concentration to lower concentration without usage of energy.
Endocytosis	:	Intaking of large sized liquid or solid macromolecules inside the cell through plasma membrane.
Euchromatin	:	Genetically active and loose part of chromatin.
Exocytosis	:	Expelling of cellular secretions or wastes out of cell through PM.
Facilitated diffusion	:	Diffusion in the presence of carriers.
Grana	:	Stacks of thylakoids.
Heterochromatin	:	Metabolically inactive and tightly coiled part of chromatin.
Heterophagy	:	Digestion of food or germs taken from outside inside the cell.

Hydrolysis	:	Breaking of complex biomolecules by addition of water.
Hydrophillic	:	Having affinity for water.
Hydrophobic	:	Having no affinity for water.
Hypertonic	:	Solution exerting greater osmotic pressure than cytoplasm.
Hypotonic	:	Solution exerting lesser osmotic pressure than cytoplasm.
Leucoplasts	:	Colourless plastids.
Lignification	:	Deposition of lignin in secondary cell wall.
Microvilli	:	Electron-microscopic evaginations of plasma membrane of intestinal cells to increase absorptive area.
Middle lamella	:	Binding layer between the adjacent plant cells.
Osmosis	:	Movement of water or any solvent from lower concentration to higher concentration through plasma membrane.
Phagocytosis (cell eating)	:	Ingestion of extracellular solid particles inside the cell.
Pinocytosis (cell drinking)	:	Intaking of large sized liquid droplets inside the cell.
Plasmodesma	:	Fine cytoplasmic strands which interconnect adjacent plant cells.
Plasmolysis	:	Shrinkage of cytoplasm of plant cell when placed in a hypertonic salt solution.
Plastidone	:	DNA molecule present inside the plastids.
Polysome	:	A group of ribosomes attached on same mRNA strand.
Quantasome	:	Site of the photochemical reactions present in thylakoid membrane.
Residual body	:	Lysosome with only undigested food.
Suberin	:	A water-proofing material secreted by cork cells and endodermal cells.
Thixotropism	:	Interchanging ability of sol and gel phases of cytoplasm.
Tonoplast	:	Vacuolar membrane.
Tunnel proteins	:	Large sized protein molecules of cell membrane which project on its both the surfaces.

NCERT FILE Solved

NCERT Exercise Questions

1. Which of the following is not correct?
- **(a) Robert Brown discovered the cell**
- **(b) Schleiden and Schwann formulated the cell theory**
- **(c) Virchow explained that cells are formed from pre-existing cells**
- **(d) A unicellular organism carries out its life activities within a single cell**

Ans. (a) Cell was discovered by Robert Hooke (1665).

2. New cells generate from :
- **(a) Bacterial fermentation**
- **(b) Regeneration of old cells**
- **(c) Pre-existing cells**
- **(d) Abiotic materials**

Ans. (c).

3. Match the following :

Column I	Column II
(a) Cristae	(i) Flat membranous sacs in stroma
(b) Cisternae	(ii) Infoldings in mitochondria
(c) Thylakoids	(iii) Disc-shaped sacs in Golgi apparatus

Ans. (a) (ii); (b) (iii); (c) (i).

4. Which of the following is correct?
- **(a) Cells of all living organisms have a nucleus**
- **(b) Both animal and plant cells have a well defined cell wall**
- **(c) In prokaryotes, there are no membrane-bound organelles**
- **(d) Cells are formed *de novo* from abiotic materials**

Ans. (c).

5. What is mesosome in a prokaryotic cell? Mention the functions that it performs?

Ans. Mesosome is infold of plasma membrane of a Gram positive bacterium. It increases the surface area of respiratory membrane and helps in replication of DNA and their separation.

6. How do neutral solutes move across the plasma membrane? Can the polar molecules also move across it in the same way? If not, then how are these transported across the membrane?

Ans. Neutral molecules e.g. non-electrolytes like copper sulphate molecules move along concentration gradient by simple diffusion. The polar molecules cannot pass across plasma membrane by simple diffusion because of bipolar nature of lipid bilayer. The polar molecules pass through plasma membrane by the process of **facilitated diffusion** which is associated with certain **carrier protein molecules**, called **permeases**, and occurs through specific channels of the carrier molecules.

7. Name two cell organelles that are double membrane-bound? What are the characteristics of these cell organelles? State their functions and draw labelled diagrams of both.

Ans. (i) Two double membrane-bound cell organelles of eukaryotic cells are : **Mitochondria** and **chloroplasts.**

(ii) Description of mitochondrion : See pages 31–33 of chapter 8.

Description of chloroplast : See pages 33–34 of chapter 8.

8. What are the characteristics of prokaryotic cells?

Ans. (i) These have primitive nucleus, called **nucleoid,** which lacks the nuclear membrane and nucleolus. Genetic material is formed of single and circular chromosome formed of *ds*DNA but not associated with histones.

(ii) **Cell wall** is generally present and is formed of **muramic acid.**

(iii) Membrane-bound cell organelles like ER, Golgi body, mitochondria, etc. are absent.

(iv) Ribosomes are of **70S** types.

(v) **Mitotic spindle** is not formed during cells division.

(vi) Cytoplasm does not show **cyclosis.**

9. Multicellular organisms have division of labour. Explain.

Ans. In multicellular organisms, different cells become specialised in their structure to perform specialised functions and coordinate to form different types of tissues which coordinate to form different organs. Each organ is specialised to perform a specific function. This increases their working efficiency and increases their chances of survival.

10. Cell is the basic unit of life. Discuss in brief.

Ans. Basic unit of life is cell in unicellular organisms like *Amoeba* and *Paramecium*, all the functions are performed within a cell and division of labour is between the various cell organelles. In multicellular organisms, division of labour is between different cells/tissues/organs of body.

11. What are nuclear pores? State their function.

Ans. Nuclear pores are apertures present in the nuclear membrane and help in nucleocytoplasmic interaction. These allow the passage of ribosomal subunits, RNAs and proteins.

12. Both lysosomes and vacuoles are endomembrane structures, yet they differ in terms of their functions. Comment.

Ans. Lysosomes are the centres of **intracellular digestion** while vacuoles are **centres of storage** of water, nutrients, minerals, etc. and exert turgor pressure. Though lysosomes and vacuoles differ in their function while both of these are endomembrane structures because these are formed from the biomembranes.

13. Describe the structure of the following with the help of labelled diagrams :

(i) Nucleus **(ii) Centrosome.**

Ans. (i) **Nucleus** : See pages 42–44 and Fig. 38 of chapter 8

Centrosome : See pages 36 and Fig. 33 of chapter 8.

14. What is a centromere? How does the position of centromere form the basis of classification of chromosomes? Support your answer with a diagram showing the position of centromere on different types of chromosomes.

Ans. See pages 44-45 and Fig. 42 A of chapter 8.

NCERT Exemplar Problems

A. MULTIPLE CHOICE QUESTIONS

1. A common characteristic feature of plant sieve tube cells and most of mammalian erythrocytes is:

(a) Absence of mitochondria
(b) Presence of cell wall
(c) Presence of haemoglobin
(d) Absence of nucleus

2. Select one which is not true for ribosome:

(a) Made of two sub units
(b) Form polysome
(c) May attach to mRNA
(d) Have no role in protein synthesis

3. Which one of these is not a eukaryote?

(a) *Euglena*
(b) *Anabaena*
(c) *Spirogyra*
(d) *Agaricus*

4. Which of the following dyes is best suited for staining chromosomes?

(a) Basic Fuchsin
(b) Safranin
(c) Methylene blue
(d) Carmine

5. Different cells have different sizes. Arrange the following cells in an ascending order of their size. Choose the correct option among the followings:

(i) Mycoplasma (ii) Ostrich eggs
(iii) Human RBC (iv) Bacteria

Options:

(a) i, iv, iii & ii (b) i, ii, iii & iv
(c) ii, i, iii & iv (d) iii, ii, i & iv

6. Which of the following features is common to prokaryotes and many eukaryotes?

(a) Chromosomes present
(b) Cell wall present
(c) Nuclear membrane present
(d) Sub-cellular organelles present

7. Who proposed the fluid mosaic model of plasma membrane?
   (a) Camillo Golgi
   (b) Schleiden and Schwann
   (c) Singer and Nicolson
   (d) Robert Brown
8. Which of the following statements is true for a secretory cell?
   (a) Golgi apparatus is absent
   (b) Rough Endoplasmic Reticulum (RER) is easily observed in the cell
   (c) Only Smooth Endoplasmic Reticulum (SER) is present
   (d) Secretory granules are formed in nucleus.
9. What is a tonoplast?
   (a) Outer membrane of mitochondria
   (b) Inner membrane of chloroplast
   (c) Membrane boundary of the vacuole of plant cells
   (d) Cell membrane of a plant cell
10. Which of the following is not true of a eukaryotic cell?
   (a) It has 80S type of ribosome present in the mitochondria
   (b) It has 80S type of ribosome present in the cytoplasm
   (c) Mitochondria contain circular DNA
   (d) Membrane bound organelles are present
11. Which of the following statements is not true for plasma membrane?
   (a) It is present in both plant and animal cell
   (b) Lipid is present as a bilayer in it
   (c) Proteins are present integrated as well as loosely associated with the lipid bilayer
   (d) Carbohydrate is never found in it
12. Plastid differs from mitochondria on the basis of one of the following features. Mark the right answer:
   (a) Presence of two layers of membrane
   (b) Presence of ribosome
   (c) Presence of chlorophyll
   (d) Presence of DNA
13. Which of the following is not a function of cytoskeleton in a cell?
   (a) Intracellular transport
   (b) Maintenance of cell shape and structure
   (c) Support of the organelle
   (d) Cell motility
14. The stain used to visualise mitochondria is:
   (a) Fast green (b) Safranin
   (c) Acetocarmine (d) Janus green

ANSWERS

1. (a); **2.** (d); **3.** (b); **4.** (d); **5.** (a); **6.** (b); **7.** (c); **8.** (b); **9.** (c); **10.** (a);
11. (d); **12.** (c); **13.** (a); **14.** (d).

HINTS FOR SOME DIFFICULT MULTIPLE CHOICE QUESTIONS

1. (a) : Because sieve tube cells are dead cells while mammalian RBCs are anaerobic in function.

8. (b) : Most of cellular secretion are proteinous in nature and are synthesized in the ribosomes bound on the elements of RER.

14. (d): Janus green is a basic vital stain employed to stain mitochondria. It was introduced by **Leonor Michaelis** (1900). In the presence of oxygen, it becomes oxidized and gives blue colour.

B. VERY SHORT ANSWER TYPE QUESTIONS

1. What is significance of vacuole in a plant cell?

Ans. Vacuole in a plant cell stores water, minerals, excretory products and other materials against the concentration gradient.

2. What does "S" refer in a 70S and 80S ribosome?

Ans. Term "S" refers to **sedimentation coefficient** or **Svedberg unit** as it was proposed by Svedberg. It is the measure of density and size of ribosome. It indicates rate of sedimentation of organelle in a centrifuge.

3. Mention a single membrane bound organelle which is rich in hydrolytic enzymes.

Ans. Lysosome.

4. What are gas vacuoles? State their functions?

Ans. Gas vacuoles are present in **Cyanobacterial cells** (blue green algae) and photosynthetic bacteria. These contain metabolic gases and provide **buoyancy** to them to float on water surface.

5. What is the function of a polysome?

Ans. When several ribosomes are attached on a single mRNA, it is called **polysome.** It is formed when many same type of proteins are to be synthesized by same mRNA molecule.

6. What is the feature of a metacentric chromosome?

Ans. A metacentric chromosome is characterised by presence of centromere at the centre so that two arms are equal sized.

7. What is referred to as satellite chromosome?

Ans. A satellite chromosome is characterised by presence of a non-staining subterminal secondary constriction and a knob-like satellite.

C. SHORT ANSWER TYPE QUESTIONS

1. Discuss briefly the role of nucleolus in the cells actively involved in protein synthesis.

Ans. Nucleolus is the site of biosynthesis and storage of r-RNA. During cell division, r-RNA is released which combines with cytoplasmic proteins to form **ribosomes** which synthesize proteins so nucleolus is called **ribosome factory.** Nucleoli are large-sized and more in number in those cells which are actively involved in protein synthesis.

2. Explain the association of carbohydrate to the plasma membrane and its significance.

Ans. Carbohydrates form about 1 – 5% of chemical composition of plasma membrane. These occur either as glycoproteins or glycolipids only on outer surface of plasma membrane. These help in cellular recognition, blood grouping and immune response.

3. Comment on the cartwheel structure of centriole.

Ans. Cartwheel structure lies inside the microtubules of centrioles. It is formed of a central hub and 9 radial spokes of proteins. Each radial spoke ends into a thickened X-body. Adjacent X-bodies are linked to another thickened Y-body which is connect to A–C linker on outer side.

4. Briefly describe the cell theory.

Ans. Cell theory was proposed by **Schleiden and Schwann** (1839) and states:

(i) Cells are structural units of organisms.

(ii) Each cell is a mass of protoplasm (with cytoplasm and nucleus) and is bounded by a plasma membrane.

(iii) Cells perform all the metabolic activities so are physiological units of cells.

(iv) New cells are formed *de novo* from abiotic materials.

5. Differentiate between Rough Endoplasmic Reticulum (RER) and Smooth Endoplasmic Reticulum (SER).

Ans. Refer **Table 11** of the chapter.

6. Give the biochemical composition of plasma membrane. How are lipid molecules arranged in the membrane?

Ans. Biochemical composition of plasma membrane is: Proteins = 58-59%, Lipids = 40% and Carbohydrates = 1–5%. Ratio of proteins and lipids varies in different cell types e.g. in PM of human RBC proteins and lipids occur in 52% and 40%. Lipids generally occur as **phospholipids** which occur in **bilayer arrangement.** Their hydrophobic tails face each other, while hydrophilic heads face in opposite directions.

7. What are plasmids? Describe their role in bacteria.

Ans. Plasmids are extra-nuclear rings of genetic material (i.e. DNA present in some bacteria (e.g. *Eschrichia coli*). These have genes of some peculiar characters like fertility factory, antibiotic resistance, etc.

8. What are histones? What are their functions?

Ans. Histones are **basic proteins** associated with DNA in the chromatin of the chromosomes. Histones help in compact packaging of DNA. A histone octomer, called **nu-body**, forms core on which DNA is wrapped to form repeated bead-like structures called **nucleosomes.**

D. LONG ANSWER TYPE QUESTIONS

1. What structural and functional attributes must a cell have to be called a living cell?

Ans. **(i)** Must be formed of a mass of protoplasm bounded by a plasma membrane which may be covered by a cell wall.

(ii) Protoplasm must have incipient or true nucleus with one or more chromosomes which contain DNA.

(iii) Cytoplasm must have at least some sub-cellular organelles e.g. ribosomes., Cytoplasm is the main site of metabolic functions.

(iv) Must be capable of independent existence especially in unicellular organisms.

(v) Must be capable of performing all metabolic functions of life e.g. growth, irritability, responsiveness, reproduction, etc.

2. Briefly give the contribution of following scientists in formulating the cell theory:

(a) Robert Virchow (b) Schleiden and Schwann.

Ans. **(a) Rudolf Virchow:** He proposed "**Theory of cell lineage**" which states "*Omnis cellula e cellula*" which means that new cells are formed from the pre-existing cells and not *de novo*.

(b) Schleiden and Schwann

Schleiden (1838) stated that all plant cells have similar basic structure and have a cell wall.

Schwann (1839) proposed **cell hypothesis** which states that the bodies of both animals and plants are formed of cells and cellular products. He also reported the presence of plasma membrane in different types of animal cells and presence of cell wall as a unique character of the plant cells.

3. Is extragenomic DNA present in prokaryotes and eukaryotes? If yes, indicate their location in both the types of organisms.

Ans. Extragenomic DNA is present in both prokaryotes and eukaryotes. In some **prokaryotes** e.g. bacteria like *Escherichia coli*, extragenomic DNA is present in **plasmids** which have genes for some peculiar phenotypic character like antibiotic resistance and sexuality.

In **Eukaryotes**, extra genomic rings of DNA are present inside the inner chamber of mitochondria of both plant and animal cells so called **mitochondrial DNA**; and stroma of plastids so called **plastidome.**

4. Structure and function are correlatable in living organisms. Can you justify this by taking plasma membrane as an example?

Ans. **(a)** Plasma membrane of intestinal cells is raised to form **microvilli** to increase surface are of absorption of nutrients.

(b) Plasma membrane of adjacent animal cells form **interdigitations** for their interlocking and more exchange of materials.

(c) **Tight junctions** and **desmosomes** help in **cell-adhesion.**

(d) Proteinous pipe-like **gap junctions** between adjacent cell membranes help in movement of ions and biomolecules between the cells.

These prove that there is a correlation between the structural features of plasma membrane and their function.

5. Eukaryotic cells have organelles which may:

(a) Not be bound by a membrane.

(b) Bound by a single membrane.

(c) Bound by a double membrane.

Group the various sub-cellular organelles into these three categories.

Ans. (a) Cell organelle not bounded by a membrane are: Ribosomes, Centriole, Basal body, etc. and also nucleolus.

(b) Cell organelles bounded by single membrane are: Lysosome, Peroxisomes, Spherosomes, Glyoxisomes, Vacuoles, Cilia, Flagella, etc.

(c) Cell organelles bounded by double membrane are: Endoplasmic reticulum; Golgi body; Mitochondria; Plastids; Nucleus; etc.

6. The genomic content of the nucleus is constant for a given species where as extra-chromosomal DNA is found to be variable among the members of a population. Explain.

Ans. The genomic content of nucleus is species specific e.g. 23 pairs of chromosomes in all the human beings of the world. It is related to hereditary informations. Each chromosome has a specific number of genes present linearly in the specific sequence. This species specific genomic content is maintained by its duplication in S-phase followed by its specific arrangement and separation during M-phase of the cell cycle. Loss of any chromosome causes loss of many genes which is generally fatal.

But the content of extra-chromosomal DNA is not species specific as its doubling and separation is a random process and may or may not occur. The genes of extra-genomic DNA are not so vital for the survival of organism.

7. Justify the statement, "Mitochondria are power houses of cell."

Ans. Mitochondria are called "**power houses**" or "**ATP mills**" or "**storage batteries**" of the cells as these have structural and physiological adaptations to form ATP molecules with biologically useful energy:

(i) There are large sized in metabolically active cells.

(ii) These are more in number in metabolically active cells like growing, contractile, secretory and dividing cells.

(iii) Inner mitochondrial membrane is produced into **cristae** to increase the surface area of cell respiration.

(iv) Each crista has F_o-F_i **particles** (also called **oxysomes**) whose base piece has proton channel while its head has **ATP synthetase** enzyme to form ATP by phosphorylation of ADP.

(v) Inner mitochondrial membrane has enzymes and carrier molecules of ETC.

(vi) Mitochondrial matrix of inner chamber has enzymes of Kreb's cycle.

8. Is there a species specific or region specific type of plastids? How does one distinguish from the other?

Ans. (i) **Distribution of plastids depends upon specific regions** of the plants. Those parts of plant body which are not exposed to light e.g. roots, rhizomes and seeds, are colourless and without grana and chlorophyll and are called **leucoplasts**. These are mainly involved in storage of food e.g. starch-storing **amyloplasts;** protein-storing **aleuronoplasts** and fat-storing **elaioplasts.**

But those parts of plants body which are exposed to light have coloured plastids e.g. those of mesophyll cells have photosynthetic pigments and are green coloured so are called **chloroplasts.** While those of flowers and fruits have some other pigments, and are called **chromoplasts**, and help in pollination and dispersal of fruits or seeds.

(ii) Types of plastids also depend upon the specific specificity of the plants e.g. **C_3-plants** have **monomorphic chloroplasts** (with grana) only in mesophyll cells of the leaves but chloroplasts are absent from bundle sheath cells. But **C_4-plants** show **kranz anatomy** and have two types of chloroplasts: **Agranal chloroplasts** in bundle sheath cells and **granal chloroplasts** in mesophyll cells.

9. Write the functions of the following:

(a) Centromere; (b) Cell wall; (c) Smooth ER;

(d) Golgi apparatus; and (e) Centrioles.

Ans. (a) **Centromere.** It is a lightly-stained constriction on a chromosome at which two sister chromatids are joined to each other. It has two disc-like **kinetochores** on which chromosomal spindle fibres are attached during cell division.

(b) **Cell wall:** (i) It **Protects** the cell from mechanical injuries and entry of germs.

(ii) It provide **mechanical support** and **definite shape** to cell.

(iii) Suberin and cutin prevent evaporation of water.

(iv) It helps in **cellular interactions** and also act as barrier to undesirable biomolecules.

(c) **SER.** It is involved in **synthesis of lipids** (e.g. triglycerides) and **steroid hormones** (e.g. testosterone, Estrogens, etc.); contraction of muscle cells and detoxification of harmful drugs and carcinogens.

(d) **Golgi apparatus.** It **packages the cellular secretions** into the secretory vesicles; **glycosylation** (addition of carbohydrates) of proteins and lipids, formation of **acrosome**, **Primary lysosomes** and **cell plate.**

(e) **Centrioles.** These form **asters and spindle apparatus** during cell division in animal cells; and form **basal bodies** to give rise to cilia and flagella.

10. Are the different types of plastids interchangeable? If yes, give examples where they are getting converted from one type to another.

Ans. Yes, the different types of plastids are interchangeable e.g.

(i) Chromoplasts are formed from green-coloured chloroplasts by replacement of chlorophyll by red-coloured **lycopine** in tomatoes and **capsanthin** in red pepper.

(ii) In root cells of carrot, red-coloured chromoplasts are formed from the colourless leucoplasts by development of red-coloured **carotenes.**

HOTS Higher Order Thinking Skills & Brain Twisting

QUESTIONS WITH ANSWERS

Very Short Answer Questions *One mark each*

1. Which type of enzyme are present in the lysosomes?

Ans. Acid hydrolases.

2. Why are the phospholipids called amphipathic molecules?

Ans. Because their heads are hydrophilic while their tails are hydrophobic.

3. Enlist two peculiar characters of prokaryotic cell.

Ans. Presence of 70 S ribosomes and incipient nucleus called nucleoid.

4. What is chemical nature of ribosomes?

Ans. Ribosomes are formed of r-RNA and proteins so are called RNP particles.

5. Which type of ER is well developed in lipid synthesizing and protein synthesizing cells?

Ans. SER is well developed in lipid synthesizing cells, while RER is well developed in protein synthesizing cells.

6. What do you mean by *"omne cellula e cellula".*

Ans. New cells are formed by division of pre-existing cells.

7. Give the relationship between cell size and surface area/volume ratio.

Ans. Small sized cells have more surface area/volume ratio so have more exchanging power.

8. State one difference between cell wall of bacterium and a plant cell.

Ans. Cell wall of bacterium is formed of peptidoglycan (murein) while that of plant cell is mainly formed of cellulose.

9. Define facilitated diffusion.

Ans. Diffusion in the presence of carrier proteins is called facilitated diffusion e.g. fructose absorption occurs by it.

10. Name two semiautonomous cell-organelles.

Ans. Mitochondria and plastids.

11. Which cellular structures form the cytoskeleton?

Ans. Microtubules, microfilaments and intermediate filaments.

12. Give microtubular arrangement of centriole and cilium.

Ans. Centriole has 9+ 0 microtubular arrangement, while cilium has 9 + 2 microtubular arrangement.

13. Give the function of peroxisomes.

Ans. Formation and degradation of hydrogen peroxide.

14. Why the nucleus is called "director of cell"?

Ans. Because it controls and coordinates all the cellular functions.

15. Give the technical term for the darkly stained and transcriptionally inactive part of chromatin.

Ans. Heterochromatin.

16. State one difference between cystoliths and raphides.

Ans. Cystoliths are crystals of calcium carbonate, while raphides are crystals of calcium oxalate.

Short Answer Questions *Two marks each*

1. Differentiate between Gram positive and Gram negative bacteria.

Ans. **Gram positive bacteria** are purple stained with Gram stain and have monolayered cell wall with 70-80% murein but less lipids, while **Gram negative bacteria** are not stained with Gram stain, two-layered cell wall with only 10-20% murein but more lipids.

2. Enlist four peculiar features of fluid-mosaic model of plasma membrane.

Ans. **(i)** It is lipoproteinous and trilaminar.

(ii) Phospholipid bilayer is fluidy in which phospholipid molecules show transitional movements as well as flip-flop movements.
(iii) Proteins are globular and are of two types : **Extrinsic** and **intrinsic** proteins.
(iv) Carbohydrates are associated with outer surface of plasma membrane.

3. Give significance of osomosis.

Ans. Osmosis helps in absorption of water by the roots, opening and closing of stomata, turgor movements of leaflets in *Mimosa*, seed germination, etc.;

4. Differentiate pinocytosis and phagocytosis.

Ans. Refer Table 7 of chapter-8.

5. List the objectionable postulate of cell theory. In which way, it was modified in cell principle?

Ans. Most objectional postulate of cell theory was that new cells are formed *de novo* analogous to formation of crystals. Later studies showed that new cells are formed by growth and division of pre-existing cells.

6. Enlist two main differences between SER and RER.

Ans. Reference Table 11 of chapter-8

7. What is peculiar about mitochondrial DNA?

Ans. Mt. DNA is circular, double stranded and not associated with histones so resembles prokaryotic DNA.

8. What is nucleosome? Give its chemical nature.

Ans. These are darkly coloured dense bodies on a chromatin fibre and each is formed of a histone octomer and associated DNA.

9. Differentiate between microtubules and microfilaments.

Ans. Refer Table 21 of chapter-8.

10. Enlist two similarities between a mitochondrion and a bacterium.

Ans. (i) Both have 70S ribosomes and circular DNA molecules.
(ii) Cristae of mitochondria are comparable to mesosomes of bacteria.

Short Answer Questions *Three marks each*

1. What do you understand by active transport across a cell membrane? Explain with one example.
2. Enlist the main postulates of cell theory. Who proposed the cell theory?
3. Discuss the relationship between cell size and its exchanging power.
4. Tabulate six differences between a prokaryotic cell and a eukaryotic cell.
5. Enlist the functions of endoplasmic reticulum.
6. Draw a labeled diagram showing ultrastructure of a chloroplast. Why it is called semiautonomous cell organelle?
7. Why is plasma membrane called a semipermeable membrane? Give its significance.
8. Give the structure and functions of nuclear membrane.

Long Answer Questions *Five marks each*

1. Give the historical hierarchy of cell structure.
2. Give an account of prokaryotic cell.
3. Describe polymorphism in lysosomes.
4. Explain the fluid mosaic model of plasma membrane.
5. Enumerate the structure and functions of true nucleus.

QUICK MEMORY TEST

A. Say True or False

Write 'True' or 'False'.

1. Centriole has 9 + 2 microtubular arrangement while cilium has 9 + 0 microtubular arrangement.
2. Transcriptionally inactive chromatin is called heterochromatin.
3. "Cell within the Cell" is stated for mitochondria and chloroplasts.
4. Lipid storing plastids are aleuroplasts, while protein storing plastids are elaioplasts.
5. ETS enzymes are located on inner mitochondrial membrane, while enzymes of Kreb's cycle are located in the mitochondrial matrix.

6. The prokaryotes have both 70S and 80S ribosomes.
7. In prokaryotic cells, respiratory enzymes are located on plasma membrane.
8. Genophore is another name of nucleoid of prokaryotic cells.
9. Solid particles are ingested by pinocytosis.
10. Membranes are useful for compartmentalisation of cells.
11. Phospholipid molecule is an amphipathic molecule.
12. Diffusion is a passive process while facilitated diffusion is an active process.
13. Functional part of DNA is called **euchromatin**, while non-functional part is called **heterochromatin**.
14. Structural and functional units of chloroplasts are grana.
15. Ribosomes are also called Palade particles.

B. Complete the missing links

1. ..... are the stacks of closely packed thylakoids.
2. ..... type ribosomes are found in the prokaryotes, while ..... type ribosomes are found in eukaryotes.
3. ..... surrounds the central vacuole.
4. Non-living structures of the cytoplasm are called ..... .
5. ..... is metal ion present at the centre of chlorophyll.
6. Starch storing plastids are called ..... .
7. Extensive infoldings of mitochondrial membrane are ..... .
8. Transcriptionally active chromatin is called ..... .
9. Chemically, the ribosomes are formed of ..... and ..... .
10. Stalked particles on the inner mitochondrial membrane are ..... .
11. ..... microtubular arrangement is found in the cilium, while ..... microtubular arrangement is found in the centriole.
12. Power houses of the cell are ..... .
13. The acrosome of the sperm is formed from ..... .
14. Single membrane bound organelles are ..... and ..... .
15. Structural and functional units of chloroplasts are ..... .
16. Naked and circular DNA molecules are found in ..... and ..... .
17. Hydrolytic enzymes are located in ..... .
18. An organelle without a limiting membrane ..... .
19. ..... are called suicidal bags of the cell.
20. Smallest sized prokaryote is ..... .
21. Passive transport includes ..... and ..... .
22. Active intake of macromolecules and particulate materials by the cell is called ..... .
23. Shrinking of a plant cell in a hypertonic solution is called ..... .
24. ..... is an amphipathic molecule.
25. Exchange of gases at lung alveoli occurs by ..... while intaking of glucose by a cell occurs by ..... .

C. Choose the correct alternative

1. Living cytoplasmic structures are called **cell organelles/cell inclusions**.
2. Nucleoid is found in **prokaryotic cells/eukaryotic cells**.
3. Ingrowths of plasma membrane of a bacterium are called **polysome/mesosomes**.
4. Long sized and tubular structures found in Gram–ve bacteria and helping in conjugation are called **pili/fimbriae**.
5. Proteins form about **59%/40%** of plasma membrane.
6. Water resistant barrier of plasma membrane is formed by **protein/phospholipid** molecules.
7. When a flaccid cell is placed in a hypotonic solution, it becomes **plasmolysed/deplasmolysed**.
8. **ER/Golgi complex** is involved in glycosylation of proteins.
9. Naked sub-cellular organelle is **lysosome/ribosome**.
10. Enzymes of Kreb's cycle are found in **outer chamber/inner chamber/inner membrane** of mitochondrion.
11. Light-independent reactions of photosynthesis occur in **thylakoids/stroma** of chloroplast.
12. 9 + 2 microtubular arrangement is found in **Basal body/ flagellum**.
13. **Gas vacuoles/contractile vacuoles** help in osmoregulation.
14. Lightly stained and transcriptionally active part of chromatin is called **euchromatin/heterochromatin**.
15. A chromosome with a centromere near its centre is called **Acrocentric/metacentric/submetacentric** chromosome.

Answers QUICK MEMORY TEST

A. Say True or False

1. False ; **2.** True; **3.** True; **4.** False ; **5.** True; **6.** False; **7.** True; **8.** True ; **9.** False ; **10.** True ; **11.** True ; **12.** False; **13.** True; **14.** False; **15.** True.

B. Complete the missing links

1. Grana; **2.** 70S, 80S; **3.** Tonoplast; **4.** Cell Inclusions; **5.** Magnesium; **6.** Amyloplasts; **7.** Cristae; **8.** Euchromatin; **9.** rRNA, proteins; **10.** Oxysomes; **11.** 9 + 2, 9 + 0; **12.** Mitochondria; **13.** Golgi apparatus; **14.** Lysosomes, Peroxisomes; **15.** Quantasomes; **16.** Mitochondria, plastids; **17.** Lysosomes; **18.** Ribosome; **19.** Lysosomes; **20.** PPLO; **21.** Diffusion, osmosis; **22.** Endocytosis; **23.** Plasmolysis; **24.** Phospholipid; **25.** Diffusion, active transport.

C. Choose the correct alternative

1. Cell organelles; **2.** Prokaryotic cells; **3.** Mesosomes; **4.** Pili; **5.** 59%; **6.** Phospholipid; **7.** Deplasmolysed; **8.** Golgi complex; **9.** Ribosome; **10.** Inner chamber ; **11.** Stroma; **12.** Flagellum; **13.** Contractile vacuoles ; **14.** Euchromatin; **15;** Submetacentric.

REVISION EXERCISES

Very Short Answer Questions

One mark each

1. What does "Theory of Lineage" state? Give its significance.
2. Name the three basic components of cell.
3. Define eutyly.
4. State one major difference between prokaryotic cell and eukaryotic cell.
5. Why the plasma membrane of a bacterium is called respiratory membrane?
6. What are mesosomes? State their function.
7. Define a nucleoid.
8. Give the term for the extra-nuclear rings of DNA present in the cytoplasm of *Escherichia coli*.
9. How does the bacterial flagellum differ from that of a eukaryote?
10. What are sex pili? Give their function.
11. State one major difference between Gram positive and Gram negative bacteria.
12. What is the chemical nature of plasma membrane of a eukaryotic cell?
13. Why are the phospholipid molecules called amphipathic molecules?
14. What does fluid-mosaic model of plasma membrane state?
15. Why does the plasma membrane called a selectively permeable membrane?
16. State one major difference between passive transport and active transport.
17. Define osmosis.
18. State one major difference between pinocytosis and phagocytosis.
19. State one major difference between primary cell wall and secondary cell wall.
20. What is chemical nature of middle lamella?
21. Define cyclosis.
22. Name three elements of ER.
23. Which organelle acts as intracellular circulatory system?
24. Name two subunits of 80S and 70S ribosomes.
25. Which organelle is called "engine of the cell?"
26. Give the significance of glycocalyx.
27. Name four forms of Lysosomes.
28. Name two semi-autonomous organelles.
29. Name two types of chromatin.

30. Name which cell organelle is associated with secretory activity of cell?
31. Name the cell organelles bounded by single unit membrane.
32. Which structure is called "little nucleus?"
33. Name two types of gaint chromosomes.
34. Which organelle shows polymorphism?
35. Give the chemical nature of ribosomes.
36. What is polyribosome?
37. What are cytosketetal structures?
38. Who proposed the 'cell theory'?
39. What will you call a cell not having ER, Golgi body, mitochondria, nuclear membrane etc.?
40. State one major difference between cell organelles and cell inclusions.
41. Name the three components of Golgi body.
42. Define sarcoplasmic reticulum.
43. What is glycosylation?
44. Recall that 0.9% NaCl and 5% glucose solutions are isotonic to human erythrocytes. Indicate whether each of the following solutions is hypertonic, hypotonic or isotonic. Suggest what type of changes will occur in erythrocytes when placed in : (a) 5% NaCl (b) 5% Glucose (c) 0.8% NaCl (d) 0.2% Glucose (e) 10% Glucose (f) 0.2% NaCl.
45. When a 5% glucose solution and an 8% glucose solution are separated by semi-premeable membrane, explain "
    (i) Which solution has greater osmotic pressure?
    (ii) In which direction osmosis occurs?
    (iii) Which solution will increase in volume?
46. State one major difference between SER and RER.
47. Name two cellular structures which are not covered by any unit membrane.
48. What are dictyosomes?
49. Why are the lysosomes called suicidal bags?
50. Why are the lysosomal enzymes called acid hydrolases?
51. Give the location of oxysomes.
52. Why are the mitochondria called semiautonomous organelles?
53. Name three types of leucoplasts.
54. Name the structural and functional elements of chloroplasts.
55. What is the microtubular arrangement in the centrioles?
56. State one major difference between centriole and basal body.
57. State one major difference between centriole and flagellum.
58. Define tonoplast.
59. Which cellular structure is called "director of the cell"?
60. Give the nature of nuclear membrane.
61. Name four types of chromosomes on the basis of position of centromere.
62. State one major difference between heterochromatin and euchromatin.
63. What are nucleosomes?
64. State one major difference between plant cell and animal cell.
65. Expand the term NOR.

ANSWERS

1. Rudolf Virchow (1858). It states that new cells are formed from the pre-existing cells; **2.** Plasma membrane, cytoplasm and nucleus; **3.** Fixity of number of cells throughout life; **4.** Eukaryotic cells have true nucleus, while prokaryotes have incipient nucleus called nucleoid; **5.** It has components of ETC and respiratory enzymes; **6.** Infolds of plasma membrane of Gram positive bacteria. These increase the surface area of respiratory membrane and also helps in DNA replication of bacterium; **7.** An incipient nucleus of bacterium and has single and circular chromosome formed of only DNA; **8.** Plasmids; **9.** Bacterial flagellum is monofibrillar and is formed of flagellin protein, while eukaryotic flagellum is formed of 11 microtubules of tubulin protein; **10.** These are hair-like evaginations of male bacterial plasma membrane. These help in binding the female bacterium during conjugation; **11.** Gram positive bacteria take Gram stain and appear purple coloured while Gram negative bacteria do not absorb Gram stain; **12.** Lipoproteinous and trilaminar; **13.** Their head is hydrophilic while their tails are hydrophobic in nature; **14.** Protein icebergs in a sea of lipid molecules; **15.** It allows only selected quantities of only selected bio-molecules to pass through; **16.** Passive transport is not energy dependent while active transport is energy-dependent; **17.** Movement of water or any other solvent molecules from a region of lower concentration to a region of higher concentration through a semipermeable membrane; **18.** Pinocytosis involves intaking of large sized liquid macrobiomolecules through plasma membrane, while phagocytosis is intaking of solid

macrobiomolecules through it; **19.** Primary cell wall is outer, elastic, thinner wall while secondary cell wall is inner, thicker and inelastic wall deposited with cutin or lignin or suberin; **20.** Formed of calcium pectates; **21.** Streaming movement of cytoplasm; **22.** Cisternae, vesicles and tubules; **23.** ER; **24.** 60S & 40S, 50S & 30S subunits; **25.** Ribosomes; **26.** Protection, definite shape, cellular recognition, blood grouping, immuno-suppression, etc.; **27.** Primary lysosome; secondary lysosome; autophagosome and residul body; **28.** Plastids and mitochondria; **29.** Heterochromatin and Euchromatin; **30.** Golgi body; **31.** Lysosomes, peroxisomes, sphaerosomes; **32.** Nucleolus; **33.** Polytene chromosome and Lampbrush chromosome; **34.** Lysosomes; **35.** rRNAs and proteins; **36.** Association of several ribosomes on single mRNA molecule; **37.** Microtubules; microfilaments intermediate filaments and ER; **38.** Schleiden and Schwann; **39.** Prokaryotic cell; **40. Cell organelles** are living structures of cytoplasm, while **cell inclusions** are non-living cytoplasmic structures; **41.** Cisternae, vacuoles and vesicles; **42.** A network of SER in the sarcoplasm of striated muscle fibres; **43.** Combination of the polysaccharides with the proteins to form glycoproteins in Golgi body; **44.** (*a*) Hypertonic, crenations on RBCs. (*b*) Isotonic, no change. (*c*) Hypotonic, swollen RBCs. (*d*) Hypotonic, bursting of RBCs. (*e*) Hypertonic, crenations on RBCs. (*f*) Hypotonic, bursting of RBCs; **45.** (i) 8% glucose solution. (ii) 5% to 8% glucose solution. (iii) 8% glucose solution; **46.** RER is formed of ribosomes-studded cisternae, while SER is formed of tubules without ribosomes; **47.** Ribosomes and nucleolus; **48.** Many Golgi bodies scattered in the cytoplasm of plant cells; **49.** Because after the cell death, the lysosomal enzymes cause autolysis of cell; **50.** Lysosomal enzymes are digestive and operate at pH 5.0; **51.** Knob-like structures present on inner face of inner mitochondrial membrane; **52.** As mitochondria contain all the requirements of protein synthesis; **53.** Amyloplasts, Aleuroplasts and Elaioplasts; **54.** Thylakoids; **55.** 9 + 0 arrangement; **56.** Centriole lies near nucleus, while basal body lies in ectoplasm; **57.** Centriole has 9 + 0 arrangement of microtubules, while flagellum has 9 + 2 arrangement of microtubules; **58.** Vacuolar membrane; **59.** Nucleus; **60.** It is double, porous, lipoproteinous and selectively permeable; **61.** Acrocentric, Telocentric, Submetacentric and Metacentric chromosomes; **62.** Heterochromatin is darkly stained, condensed and transcriptionally inactive parts of DNA, while euchromatin is lightly stained, extended and transcriptionally active parts of DNA; **63.** Functional units of chromonema; **64.** Plant cell has cell wall and chloroplasts but is without centriole, while animal cell lacks cell wall and chloroplasts but has centriole; **65.** Nucleolar Organising Region.

Short Answer Questions

Two marks each

1. Who proposed the cell theory? List its postulates.
2. List two main differences between prokaryotic and eukaryotic cell.
3. Differentiate types of bacteria on the basis of their shape.
4. Draw a neat and labelled diagram of a bacterial cell.
5. Discuss nucleoid in a bacterium.
6. Give the significance of diffusion.
7. Differentiate diffusion and osmosis.
8. What is active transport? Give one example of active transport.
9. What is advantage of fluid-mosaic model over other models of plasma membrane?
10. List two main differences between a plant cell and an animal cell.
11. Why is ER called cell circulatory system?
12. Give three differences between 70S and 80S ribosomes.
13. Differentiate autophagy and autolysis
14. What are thylakoids? Why are these called structural and functional units of chloroplasts?
15. Why is basal body called ciliated centriole?
16. Differentiate leucoplasts and chromoplasts.
17. Differentiate between primary cell wall and secondary cell wall.
18. What is effect of hypotonic and hypertonic salt solution on the RBCs.
19. Differentiate between passive transport and active transport.
20. Define middle lamella. Give its chemical nature and function.
21. Differentiate between cell organelles and cell inclusions.
22. Differentiate between heterophagy and autophagy.
23. How do outer membrane and inner membrane of the mitochondria differ from each other?
24. Draw a neat and labelled sketch of a plastid.
25. Differentiate between centriole and basal body.
26. List the functions of a vacuole.
27. Differentiate between Euchromatin and heterochromatin.
28. What are desmotubules? Give their function.
29. Which cellular structures act as : cell circulatory system; protein factories; power houses, kitchens of the cell, ciliated centriole and disposal units.
30. Name the various modifications of plasma membrane and explain the desmosomes.
31. Give three functions of nucleus.
32. Draw well labelled diagram of mitochondrion.

ANSWERS

1. (i) Cell theory was propounded by **Schleiden and Schwann** (1839).
   (ii) • Cells are morphological and physiological units of life.
   • New cells are formed *de novo*.
   • Each cell is a mass of protoplasm and is bounded by plasma membrane.
2. **Prokaryotic cells** have an incipient nucleus called **nucleoid** but lack the membrane-bound cell organelles, while **eukaryotic cells** have true nucleus and membrane-bound cell organelles like ER, Golgi body, mitochondria, etc.
3. **Cocci** (rounded bacteria *e.g. Diplococcus*); *Bacillus* (rod-shaped bacteria); *Vibrio* (Comma-shaped bacteria *e.g.* of cholera) and **Spirillum** (Corkscrew-shaped).
4. Refer Fig. 6 of chapter 8.
5. **Nucleoid** is the incipient nucleus of bacterium which lacks the nuclear membrane, nucleoplasm and nucleolus. It is formed of single and circular chromosome formed of double-stranded DNA but is not associated with histones proteins.
6. (i) Helps in **uniform distribution** of materials.
   (ii) Scented flowers attract the pollinating agents.
   (iii) Helps in exchange of gases at lung alveoli.
   (iv) Transpiration in plants.
7. Refer Table 6 of chapter 8.
8. Active transport is a selective and unidirectional movements of ions of molecules from lower concentration to higher concentration through a cell membrane in the presence of energy e.g. absorption of amino acids.
9. (i) It explains quasifluid state of plasma membrane, (ii) Differentiates two types of proteins, (iii) Explains functional specificity and variability in the two surfaces of plasma membrane.
10. (i) A plant cell has cell wall, and chloroplasts, while lacks centrosome.
    (ii) An animal cell does not have cell wall and chloroplasts but has centrosome.
11. Because it helps in transportation of materials in the cytoplasm in a directional flow.
12. Refer Table 14 of chapter 8.
13. Refer Table 13 of chapter 8.
14. Thylakoids are oval-shaped sacs which lie super-imposed in the stroma of chloroplasts to form grana. These have enzymes for photochemical reactions of photosynthesis as have chlorophyll containing quantasomes.
15. It has similar ultrastructure of a centriole but is always associated with cilium or flagellum.
16. Refer Table 16 of chapter 8.
17. Refer Table 10 of chapter 8.
18. In the **hypertonic** salt solution (*e.g.* 1% NaCl), RBCs undergo exosmosis and become small sized and crenated, while in the **hypotonic** salt solution (*e.g.* 0.5% NaCl), the RBCs undergo endosmosis and become swollen and spherical.
19. Refer Table 8 of chapter 8.
20. (i) **Middle lamella** is the layer between cell walls of adjacent plant cells.
    (ii) It is formed of pectates of calcium and magnesium.
    (iii) It binds the adjacent plant cells.
21. Refer Table 22 of chapter 8.
22. Refer Table 12 of chapter 8.
23. Refer Table 15 of chapter 8.
24. Refer Fig. 32 of chapter 8.
25. Refer Table 18 of chapter 8.
26. (i) Cell sap exerts **turgor pressure** which helps in cell shape.
    (ii) **Stores** water, minerals, wastes, etc.
    (iii) Helps in elongation and **growth** of the cell.
27. Refer Table 25 of chapter 8..
28. **Desmotubules** are tubular extensions of SER which pass through the plasmodesmata and connect the ER of the adjoining cells.
29. Endoplasmic reticulum; Ribosomes; Mitochondria; Chloroplasts, Basal body and Lysosomes.
30. (i) Various modifications of plasma membrane are : Microvilli; Desmosomes; Interdigitations; Gap junctions; Plasmodesmata; etc.
    (ii) Desmosomes : Refer page 480 of chapter 8.
31. (i) Controls cellular functions; (ii) Controls synthesis of structural and enzymatic proteins;
    (iii) Contains genetic informations in DNA.
32. Refer Fig. 30 of chapter 8.

Short Answer Questions — *Three marks each*

1. Why membranes are referred to as 'Proteins ice-bergs in a sea of lipids'? Explain this statement.
2. If a crystal of potassium permanganate ($KMnO_4$), violet in colour, is placed on a clean layer of gelatin, the gelatin gradually becomes violet. The colour is more intense in the vicinity of crystal.
   (a) Explain this observation.
   (b) Discuss how this general process is important for living cells.
3. It is a common observation that there is an appearance of yellowish area on the leaves after the spray of a heavy does of insecticides. Investigation shows that cells have died. As the insecticides are not poisonous to plant, explain reasons for the death of the cells.
4. Differentiate between :
   (i) Osmosis and diffusion. **(ii)** Exocytosis and endocytosis.
   (iii) Exosmosis and endosmosis.
5. Compare a plant cell and an animal cell.
6. Where would the following structures be found in a cell?
   (a) Microtubules **(b)** Thylakoids **(c)** F_0–F_1 particles **(d)** Ribosomes **(e)** Nucleolus.
7. Give an account of ultrastructure and functions of mitochondrion.
8. Write briefly about the structure and functions of ribosomes.
9. Give structure and functions of nucleolus.
10. Differentiate between :
    (a) Cytoplasm and nucleoplasm.
    (b) Chromatin and chromosome.
    (c) Euchromatin and heterochromatin.
11. Define phagocytosis. Describe the mechanism and significance of phagocytosis.
12. Distinguish between : (i) extrinsic and intrinsic proteins (ii) primary and secondary lysosomes.
13. List the functions of Golgi body.
14. Name various modifications of plasma membrane. Explain microvilli.
15. Give the cytological term for the following :
    (i) Transcriptionally active part of chromatin.
    (ii) Structural and functional units of chromatin.
    (iii) Chromosome with subterminal centromere.
16. Explain Robertson's unit membrane concept. *(Himachal Board 2008)*
17. Describe the ultrastructure of nucleus. Give its two functions. *(Himachal Board 2008)*

Long Answer Questions — *Five marks each*

1. Give an account of cell theory.
2. Enumerate the cell organelles present in an Eukaryote cell. Give functions of each.
3. What is active transport? Write its mechanism.
4. Give an account of structure and functions of cell wall.
5. Discuss the structure and functions of chloroplast (plastid).
6. Describe the osmotic behaviour of plant cell.
7. Explain the unit membrane concept. How does it differ from sandwitch model?
8. Enumerate various types of modifications of plasma membrane. Give their significance.
9. Describe functions of Golgi body.

COMPETITION FILE OBJECTIVE TYPE QUESTIONS

A. MULTIPLE CHOICE QUESTIONS (MCQs):

(From AIPMT & Other Competitive Examinations)

1. A major break through in the studies of cells came with the development of electron microscope. This is because :
   (a) The resolution power of the EM is much higher than that of light microscope
   (b) The resolving power of the EM is 200-350 nm as compared to 0.1–0.2 nm for the light microscope

(c) Electron beam can pass through thick materials, whereas light microscopy requires thin sections
(d) The EM is more powerful than the light microscope as it uses a beam of electrons which has wavelength much longer than that of protons. (*CBSE 2006*)

2. Which of the following statements regarding to mitochondrial membrane is not correct?
(a) Outer membrane is permeable to all kinds of molecules
(b) Enzymes of the ETC are embedded in the outer membrane
(c) Inner membrane is highly convoluted forming a series of infoldings
(d) Outer membrane resembles a sieve (*CBSE 2006*)

3. Which of the following statements regarding cilia is not correct?
(a) The organised beating of cilia is controlled by fluxes of Ca^{2+} across membrane
(b) Cilia are hair-like cellular appendages
(c) Microtubules of cilia are composed of tubulin
(d) Cilia contain an outer ring of nine doublet microtubules surrounding two single microtubules (*CBSE 2006*)

4. The vacuole is lined by a membrane called :
(a) Tonoplast (b) Jacket (c) Cell membrane (d) Tonoplasm (*BHU 2006*)

5. Spindle fibres are made up of :
(a) Tubulin (b) Humulin (c) Intermediate filament (d) Flagellin (*BHU 2006*)

6. What is common between chloroplasts, chromoplasts and leucoplasts?
(a) Presence of pigments (b) Possession of thylakoids and grana
(c) Storage of starch, proteins and lipids (d) Ability to multiply by a fission-like process (*AIIMS 2006*)

7. r-RNA is synthesized by :
(a) Nucleus (b) Nucleolus (c) Cytoplasm (d) Endoplasmic reticulum (*Orissa JEE 2006*)

8. The biomembrane tonoplast is :
(a) Covering of cell wall (b) Covering of nucleus
(c) Covering of mitochondria (d) Covering of vacuole (*Orissa JEE 2006*)

9. Cell drinking is :
(a) Exocytosis (b) Pinocytosis (c) Phagocytosis (d) None of these (*Orissa JEE 2006*)

10. Subcellular organelle is :
(a) Peroxisome (b) Ribosome (c) Plastid (d) Lysosome (*AMU 2006*)

11. Golgi body is associated with :
(a) Packaging and storage of material (b) Cell plate formation
(c) Secretion of different substances (d) All of the above (*AMU 2006*)

12. Acrosome is formed from :
(a) Golgi body (b) Ribosome (c) Lysosome (d) ER (*AMU 2006*)

13. What does a cell show if placed in sea water?
(a) Plasmolysis (b) Reverse osmosis (c) Deplasmolysis (d) None of these (*AMU 2006*)

14. The cell wall of eukaryotic organism is made up of :
(a) Hemicellulose + pectin (b) Hemicellulose + pectin + cellulose
(c) Hemicellulose + lipids (d) Hemicellulose + chitin (*AMU 2006*)

15. The bacterial cell wall is made up of :
(a) Cellulose (b) Hemicellulose (c) Cellulose and hemicellulose
(d) Peptidoglycan (e) Glycogen (*Kerala PMT 2006*)

16. Which of the following subunit of ribosome is composed of 23S rRNA and a 5S rRNA + 32 different proteins?
(a) 50S (b) 70S (c) 30S
(d) 60S (e) 40S (*Kerala PMT 2006*)

17. Solenoid is a structure of :
(a) Nucleosomal organization with 10 nm thickness
(b) Condensed chromatin fibre with 30 nm diameter
(c) Highly condensed form of chromatid with 300 nm diameter
(d) Well organized chromatid with 700 nm thickness
(e) Well organized chromosome with 1400 nm thickness (*Kerala PMT 2006*)

18. Cell wall consists of :
(a) Lignin, hemicellulose, protein and lipid (b) Hemicellulose, cellulose, tubulin and lignin
(c) Lignin, hemicellulose, pectin and lipid (d) Lignin, hemicellulose, pectin and cellulose (*KCET 2007*)

19. The term "cytoplasm" and "nucleoplasm" were given by :
(a) Purkinje (b) Strasburger (c) Brown (d) Flemming ***(KCET 2007)***

20. Cell wall of bacterium is formed of :
(a) Cellulose (b) Hemicellulose (c) Lignin
(d) Glycogen (e) Peptidoglycan ***(Kerala PMT 2007)***

21. Which of these is mismatched?
(a) Amyloplasts = Store protein granules (b) Elaioplasts = Store lipids
(c) Chloroplasts = Contain chlorophyll pigments (d) Leucoplasts = Contain colourless pigments
(e) Chromoplasts = Contain non-chlorophyll coloured pigments ***(Kerala PMT 2007)***

22. Cristae are associated with :
(a) Endoplasmic reticulum (b) Mitochondria (c) Cytoplasm (d) Protoplasm ***(CPMT 2007)***

23. Centrosome is not present in the cells of :
(a) Higher plants (b) Lower plants (c) Higher animals (d) Lower animals ***(CPMT 2007)***

24. A cell swells up when kept in :
(a) Isotonic solution (b) Hypertonic solution (c) Hypotonic solution (d) Any of these
(CPMT; Orissa JEE 2007)

25. Site of protein synthesis is :
(a) Ribosome (b) SER (c) Golgi body (d) Lysosome ***(CPMT 2007)***

26. Which of the following is a prokaryote?
(a) *Amoeba* (b) *Spirogyra* (c) Bacteria (d) *Chlamydomonas*
(MP-PMT 2007)

27. The mineral present in the cell wall is :
(a) Na (b) Ca (c) K (d) Mg ***(MP-PMT 2007)***

28. The cell theory was proposed by :
(a) Virchow (b) Schleiden and Schwann (c) Robert Hooke (d) B. McClintock
(MP-PMT 2007)

29. Which organelle is present in more number in secretory cells?
(a) Dictyosomes (b) ER (c) Lysosomes (d) Vacuoles ***(MP-PMT 2007)***

30. Acid hydrolase is found in :
(a) Golgi body (b) ER (c) Lysosome (d) Vacuole ***(MP-PMT 2007)***

31. RNA is not found in :
(a) Chromosome (b) Plasmalemma (c) Nucleolus (d) Ribosome
(MP-PMT 2007)

32. A chromosome having centromere at its middle is :
(a) Telocentric (b) Acrocentric (c) Metacentric (d) Dicentric ***(Orissa JEE 2007)***

33. Fluid mosaic model was proposed by :
(a) Singer and Nicolson (b) Davidson and Danielli (c) Robertson (d) Watson and Crick
(Orissa JEE 2007)

34. An enzyme which increases the rate of permeability across the PM is :
(a) Permease (b) Catalase (c) Gelatinase (d) Amylase ***(Orissa JEE 2007)***

35. In bacteria, cell wall is formed of :
(a) Chitin (b) Murein (c) Pectin (d) Cellulose ***(Orissa JEE 2007)***

36. The two subunits of ribosome remain united at a critical ion level of :
(a) Magnesium (b) Calcium (c) Copper (d) Manganese ***(CBSE 2008)***

37. A polysome is formed by :
(a) A ribosome with several subunits (b) Ribosome attached to each other in a linear manner
(c) Several ribosomes attached to a single mRNA (d) Many ribosomes attached to ER ***(CBSE 2008)***

38. Vacuole in a plant cell :
(a) Lacks membrane and contains air
(b) Lacks membrane and contains water and excretory wastes
(c) Is membrane-bound and contains storage proteins and lipids
(d) Is membrane-bound and contains water and excretory wastes ***(CBSE 2008)***

39. In germinating seeds, fatty acids are degraded exclusively in the :
(a) Peroxisomes (b) Mitochondria (c) Proplastids (d) Glyoxysomes ***(CBSE 2008)***

40. Keeping in view the "fluid mosaic model" of the cell membrane, which one of the following statements is correct with respect to the movement of lipids and proteins from one lipid monolayer to the other (described as flip-flop movement)?

(a) While proteins can flip-flop lipids cannot (b) Neither proteins nor lipids can flip-flop
(c) Both lipids and proteins can flip-flop (d) While lipids can rarely flip-flop, proteins cannot
(*CBSE 2008*)

41. Flagella of prokaryotic and eukaryotic cells differ in :
(a) Type of movement and placement in cell (b) Location in cell and mode of functioning
(c) Micro-tubular organisation and type of movement (d) Micro-tubular organisation and function (*AFMC 2008*)

42. Cytoplasmic inheritance is due to :
(1) Mitochondria (2) Cilia (3) Cytoplasmic particles (4) Cell wall
(a) 1, 2 and 3 are correct (b) 1 and 2 are correct (c) 2 and 4 are correct (d) 1 and 3 are correct
(*BHU 2008*)

43. Which of the following statements are correct?
(1) Mitochondria contain DNA
(2) Ribosomes are formed of phospholipids & oligosaccharides
(3) 70s ribosomes occur in prokaryotes
(4) Ribosomes are not found in Protista & Monera
(a) 1, 2 and 3 are correct (b) 1 and 2 are correct (c) 2 and 4 are correct (d) 1 and 3 are correct
(*BHU 2008*)

44. Genes present in the cytoplasm of eukaryotic cells, are found in :
(a) Mitochondria and inherited via egg cytoplasm (b) Lysosomes and peroxisomes
(c) Golgi bodies and smooth endoplasmic reticulum (d) Plastids and inherited via male gametes
(*AIIMS 2008*)

45. What is common between chloroplasts, chromoplasts and leucoplasts?
(a) Presence of pigments (b) Possession of thylakoids and grana
(c) Storage of starch, proteins and lipids (d) Ability to multiply by fission-like process
(*AIIMS 2008*)

46. Cell theory was proposed by :
(a) Virchow (b) Schleiden and Schwann (c) Robert Hooke (d) B. McClintock
(*Har. PMT 2008*)

47. Acid hydrolases are found in :
(a) Golgi body (b) ER (c) Lysosomes (d) Vacuole (*Har. PMT 2008*)

48. The mineral present in the cell wall is :
(a) Na (b) Ca (c) K (d) Mg (*Har. PMT 2008*)

49. Which organelle is present in maximum number in secretory cells?
(a) Dictyosomes (b) ER (c) Lysosomes (d) Vacuoles (*Har. PMT 2008*)

50. The type of cell junction which facilitates cell to cell communication is :
(a) Tight junction (b) Adhering junction (c) Gap junctions
(d) Desmosomes (e) Brush borders (*Kerala PMT 2008*)

51. The phenomenon of plasmolysis is evident when cells are kept in :
(a) Hypotonic solution (b) Hypertonic solution (c) Isotonic solution (d) None of these
(*Orissa JEE 2008*)

52. Site of gluconeogenesis is :
(a) Mitochondria (b) Golgi bodies (c) Glyoxisomes (d) None of these
(*Orissa JEE 2008*)

53. The largest subunit of prokaryotic ribosomes is :
(a) 30 S (b) 40 S (c) 50 S (d) 60 S (*J & K CET 2008*)

54. Which of the following is a part of endomembrane system of eukaryotic cell?
(a) Peroxisomes (b) Chloroplasts (c) Mitochondria (d) Golgi complex
(*J & K CET 2008*)

55. Small particles projecting from the inner membrane and cristae of mitochondria are :
(a) Myeloid bodies (b) Microsomes (c) Informosomes (d) Oxysomes (*WB. JEE 2008*)

56. There is no DNA in :
(a) An enucleated ovum (b) Mature RBCs (c) Mature spermatozoan (d) Hair root (*CBSE 2009*)

57. Middle lamella is mainly composed of :
(a) Hemicellulose (b) Muramic acid (c) Calcium pectate (d) Phosphoglycerides
(*CBSE 2009*)

58. Plasmodesmata are :
(a) Lignified cemented layers between cells (b) Locomotory structures
(c) Membranes connecting the nucleus and plasmalemma (d) Connections between adjacent cells *(CBSE 2009)*

59. Cytoskeleton is made up of :
(a) Calcium carbonate granules (b) Callose deposits
(c) Cellulosic microfilaments (d) Proteinaceous filaments *(CBSE 2009)*

60. Which of the following four structures is correctly matched with the accompanying description?
(a) Plasma membrane – Outer layer of cellulose or chitin or absent.
(b) Mitochondria – Bacteria-like elements with inner membrane forming sacs containing chlorophyll and found in plant cells and algae.
(c) Chloroplasts – Bacteria-like elements with inner membrane highly folded.
(d) Golgi apparatus – Stacks of flattened vesicles *(AIIMS 2009)*

61. What is correct sequence of the steps given here? Also work out the process depicted in the steps :
(i) Homologous chromosomes move towards opposite poles of the cell; chromatids donot separate.
(ii) Chromosomes gather together at the two poles of the cell and nuclear membranes reformed.
(iii) Homologous chromosomes pair and exchange segments
(iv) Homologous chromosomes align on a central plate
(v) The haploid cells separate completely
(a) The correct sequence is : (iii) → (iv) → (i) → (ii) → (v) and the process is meiosis–I.
(b) The correct sequence is : (ii) → (i) → (v) → (iv) → (iii) and the process is mitosis.
(c) The correct sequence is : (iv) → (i) → (iii) → (ii) → (v) and the process is meiosis–I.
(d) The correct sequence is : (ii) → (v) → (iv) → (i) → (iii) and the process is mitosis *(AIIMS 2009)*

62. A cell when kept in sugar solution, gets dehydrated. Then the solution is :
(a) Hypotonic (b) Hypertonic (c) Isotonic (d) None of these *(AFMC 2009)*

63. Desmosomes are :
(a) Connecting bodies between cells (b) Fat storage cells (c) Pigment bodies
(d) None of these *(AFMC 2009)*

64. Powerhouse of the cell is :
(a) Golgi bodies (b) Mitochondria (c) Ribosomes
(d) Endoplasmic reticulum *(AFMC 2009)*

65. The prokaryotic cells are characterized by :
(a) Presence of distinct nuclear membrane (b) Absence of chromatin material
(c) Presence of distinct chromosome (d) Absence of nuclear membrane *(CPMT 2009)*

66. The endoplasmic reticulum is in continuation with :
(a) Golgi body (b) Nuclear membrane (c) Mitochondria (d) Cell wall *(CPMT 2009)*

67. In higher plants, the shape of the chloroplast is :
(a) Discoidal (b) Cup-shaped (c) Girdle-shaped (d) Reticulate *(DPMT 2009)*

68. The chief component of middle lamella in plant cell is :
(a) Potassium (b) Calcium (c) Magnesium (d) Phosphorus *(DPMT 2009)*

69. Tonoplast is the membrane surrounding the :
(a) Vacuole (b) Cytoplasm (c) Nucleus (d) Mitochondria *(DPMT 2009)*

70. A chromosome in which centromere is situated close to its end, so that one arm is very short and other very long :
(a) Acrocentric (b) Metacentric (c) Sub-metacentric (d) Telocentric *(DPMT 2009)*

71. Most of enzymes of TCA cycle are present in :
(a) Cytoplasm (b) Inner membrane space of mitochondrion
(c) Mitochondrial matrix (d) Inner mitochondrial membrane *(J&K – CET 2009)*

72. Long, flattened and usually unbranched units arranged in parallel stacks in endoplasmic reticulum are called :
(a) Cisternae (b) Cristae (c) Vesicles (d) Tubules *(J&K – CET 2009)*

73. Plasmolysis is the result of :
(a) Exosmosis (b) Endosmosis (c) Reverse osmosis (d) Diffusion
(J&K – CET 2009)

74. Flocullation or coagulation of protoplasm is the :
(a) Interchangeability between sol and gel states
(b) Ability to scatter the beam of light
(c) Erratic zig-zag movements of protoplasmic particles
(d) Ability of protoplasm to increase in size when they lose charges *(J & K – CET 2009)*

75. Quantasomes are present in :
(a) Chloroplasts (b) Mitochondria (c) Golgi body (d) Lysosome *(BVP – 2009)*

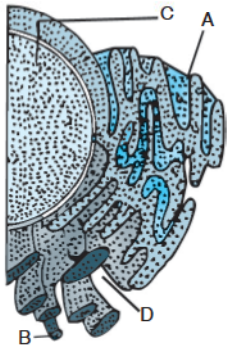
76. Which of the following cell organelles stores hydrolytic enzymes?
(a) Centrioles (b) Lysosomes (c) Chromoplasts (d) Chloroplasts *(BVP – 2009)*

77. Which of the following cell organelles is associated with photorespiration?
(a) Mitochondria (b) Peroxisomes (c) Chloroplast (d) All of these *(BVP – 2009)*

78. An elaborate network of filamentous proteinaceous structures present in the cytoplasm which helps in the maintenance of cell shape is called :
(a) Thylakoids (b) Endoplasmic reticulum (c) Plasmalemma (d) Cytoskeleton *(CBSE, 2010)*

79. Identify the components labelled A, B, C and D in the diagram below from the list (i) to (viii) given along with Components :

(i) Cristae of mitochondria (ii) Inner membrane of mitochondrion
(iii) Cytoplasm (iv) SER
(v) RER (vi) Mitochondrial matrix
(vii) Cell vacuole (viii) Nucleus



The correct components are :

	A	B	C	D
(a)	(v)	(iv)	(viii)	(iii)
(b)	(i)	(iv)	(viii)	(vi)
(c)	(vi)	(v)	(iv)	(vii)
(d)	(v)	(i)	(iii)	(ii)

(CBSE 2010)

80. Digestive enzymes hydrolases are present in :
(a) Vacuole (b) Lysosomes (c) Golgi bodies (d) Mitochondria *(AFMC 2010)*

81. When a fresh-water protozoan is placed in marine water :
(a) The contractile vacuoles become bigger in size (b) The number of contractile vacuoles increase
(c) The contractile vacuoles disappear (d) The contractile vacuoles remain unchanged
(KCET 2010)

82. Term plasmalemma was given by :
(a) Strasburger (b) Plowe (c) Hooke (d) Robertson *(UP-CPMT 2010)*

83. Cystolith contains :
(a) $CaCl_2$ (b) CaO (c) $CaCO_3$ (d) $MgCl_2$ *(UP-CPMT 2010)*

84. Which of the following match is correct?
(a) Oil storage – Rhodoplasts (b) Protein storage – Amyloplasts
(c) Starch storage – Aleuroplasts (d) Fat storage – Elaioplasts *(UP-CPMT 2010)*

85. The number of microtubules in a flagellum including those sharing three protofilaments with each other is :
(a) 11 (b) 20 (c) 22 (d) 10 *(DUMET 2010)*

86. The cytoplasm of adjacent plant cells is connected to each other by :
(a) Plasmalemma (b) Desmosome (c) Plasmodesmata (d) Plasmotubule
(DUMET 2010)

87. The long and short arms of chromosome are designated respectively as :
(a) p and q arms (b) q and p arms (c) m and p arms (d) l and s arms *(DUMET 2010)*

88. The microfilaments of eukaryotic cells are made up of :
(a) Actin (b) Albumin (c) Globulin (d) Fibrin *(DUMET 2010)*

89. Present in nucleus is :
(a) Golgi complex (b) Lysosome (c) Mitochondria (d) Chromosome
(MP-PMT 2010)

90. Which of these is wrongly matched?
(a) Chloroplasts – chlorophyll (b) Elaioplasts – starch (c) Chromoplasts – carotenoids
(d) Amyloplasts – carbohydrates (e) Aleuroplasts – proteins *(Kerala PMT 2010)*

91. Which one of the following organelles is not surrounded by any membrane?
(a) Mitochondrion (b) Vacuole
(c) Endoplasmic reticulum (d) Chloroplast (e) Ribosome *(Kerala PMT 2010)*

92. Consider the following statements.
(A) Plant cells have centrioles which are absent in almost all animal cells
(B) Ribosomes are the site of protein synthesis

(C) The middle lamella is a layer mainly of calcium carbonate which holds the different neighbouring cells together
(D) In animal cell steroidal hormones are synthesized by smooth endoplasmic reticulum
Of the above statements :
(a) (A) and (B) only are correct (b) (C) and (D) only are correct
(c) (B) and (D) only are correct (d) (A) and (D) only are correct
(e) (B) and (C) only are correct *(Kerala PMT 2010)*

93. What is mitoplast?
(a) Membrane less mitochondria (b) Another name of mitochondria
(c) Mitochondria without outer membrane (d) Mitochondria without inner membrane *(WB-JEE 2010)*

94. Cell theory is not applicable for :
(a) Bacteria (b) Fungus (c) Algae (d) Virus *(WB-JEE 2010)*

95. Mitochondria are semi-autonomous as they possess :
(a) DNA (b) DNA + RNA
(c) DNA + RNA + Ribosomes (d) Proteins *(WB-JEE 2010)*

96. Cells divide and new cells are formed from pre-existing cells. This concept was given by :
(a) Malthias Schleiden (b) Theodore Schwann
(c) Malthias Schleiden & T. Schwann (d) Rudolf Virchow *(AMU 2010)*

97. $Na^+ \setminus K^+$ pump in a cell is an example of :
(a) Osmosis (b) Diffusion (c) Passive transport (d) Active transport *(AMU 2010)*

98. Active transport is characterized by :
(a) Requires special membrane protein (b) Highly selective
(c) Requires ATP's energy (d) All of these *(AMU 2010)*

99. A typical nucleosome contains :
(a) 100 bp of DNA helix (b) 200 bp of DNA helix
(c) 300 bp of DNA helix (d) 400 bp of DNA helix *(AMU 2010)*

100. The cell membranes of adjacent cells are fused at this cell junction :
(a) Macula adherens (b) Zonula adherens (c) Zonula occuludens (d) Nexus *(AMU 2010)*

101. Disappearance of the tadpole tail during metamorphosis is brought about by :
(a) Endoplasmic reticulum (b) Golgi bodies (c) Lysosomes (d) Peroxisomes *(AMU 2010)*

102. Important site of formation of glycoproteins and glycolipids is :
(a) Vacuole (b) Golgi apparatus (c) Plastid (d) Lysosome *(CBSE 2011)*

103. Peptide synthesis inside a cell takes place in :
(a) Chloroplast (b) Mitochondria (c) Chromoplast (d) Ribosomes *(CBSE 2011)*

104. What are those structures which appear as "beads-on-string" in the chromosomes when viewed under electron microscope?
(a) Genes (b) Nucleotides (c) Nucleosomes (d) Base pairs *(CBSE 2011)*

105. In eubacteria, a cellular component that resembles eukaryotic cell is :
(a) Plasma membrane (b) Nucleus (c) Ribosomes (d) Cell wall *(CBSE 2011)*

106. Two percent solution of NaOH as compared to 18 per cent solution of glucose is :
(a) Isotonic (b) Hypotonic (c) Hypertonic (d) None of these *(AMU 2011)*

107. Which of the following is not a true organelle?
(a) Lysosome (b) Chloroplast (c) Ribosome (d) Mitochondrion *(AMU 2011)*

108. Detoxification of lipid soluble drugs and other harmful compounds in endoplasmic reticulum is carried out by :
(a) Cytochrome P 450 (b) Cytochrome bf (c) Cytochrome C (d) Cytochrome $a_1 - a_2$ *(AMU 2011)*

109. Consider the following statements and select the correct option :
A. The endomembrane system includes plasma membrane, ER, Golgi complex, lysosomes and vacuoles
B. ER helps in transportation of substances, synthesis of proteins, lipoproteins and glycoyen
C. Ribosomes are involved in protein synthesis
D. Mitochondria help in oxidative phosphorylation and generation of ATP
(a) B, C & D are correct (b) A–alone is correct (c) B–alone is correct
(d) C–alone is correct (e) D–alone is correct *(Kerala PMT 2011)*

110. The process by which water is absorbed by solids like colloids causing them to increase in volume is called :
(a) Osmosis (b) Plasmolysis (c) Imbibition
(d) Diffusion (e) Facilitated diffusion *(Kerala PMT 2011)*

111. Zone of exclusion surrounds :
(a) Golgi apparatus (b) Centrioles (c) Nucleus (d) Lysosome *(J&K CET 2011)*

112. Histone octamer contains :
(a) Eight types of histones (b) Eight histones of four different types
(c) Five types of histones (d) Six types of histones *(J&K CET 2011)*

113. Glycocalyx is associated with:
(a) Nucleolus (b) Plasma membrane (c) Nucleus (d) Nucleosome *(J&K CET 2011)*

114. When a cell is plasmolysed, it becomes:
(a) Flaccid and its TP becomes O (b) Turgid and its TP becomes O
(c) Turgid and TP becomes equal to OP (d) Flaccid and DPD becomes O *(J&K CET 2011)*

115. Ribosomal RNA is actively synthesized in:
(a) Lysosomes (b) Nucleolus (c) Nucleoplasm (d) Ribosomes *(CBSE 2012)*

116. The correct sequence of cell organelles during photorespiration is:
(a) Chloroplast, Golgi bodies, mitochondria (b) Chloroplast, RER, dictyosomes
(c) Chloroplast, mitochondria, peroxisome (d) Chloroplast, vacuole, peroxisome *(CBSE 2012)*

117. Which one of the following is wrong statement?
(a) *Anabaena* and *Nostoc* are capable of fixing nitrogen in free-living state also
(b) Root nodule forming nitrogen fixers live as aerobes under free-living conditions
(c) Phosphorus is a constituent of cell membranes, certain nucleic acids and all proteins
(d) *Nitrosomonas* and *Nitrobacter* are chemoautotrophs *(CBSE 2012)*

118. What is true about ribosomes?
(a) The prokaryotic ribosomes are 80S whereas "S" stands for sedimentation coefficient
(b) These are composed of ribonucleic acid and proteins
(c) These are found only in eukaryotic cells
(d) These are self-splicing introns of some RNAs *(CBSE 2012)*

119. Nuclear membrane is absent in:
(a) *Penicillium* (b) *Agaricus* (c) *Volvox* (d) *Nostoc* *(CBSE 2012)*

120. Select the correct statement from the following regarding cell membrane:
(a) Na^+ and K^+ ions move across cell membrane by passive transport
(b) Proteins make upto 60 – 70% of the cell membrane
(c) Lipids are arranged in a bilayer with polar heads towards inner side
(d) Fluid mosaic model of cell membrane was proposed by Singer and Nicolson

121. $Na^+|K^+$ pump is associated with:
(a) Passive transport (b) Active transport (c) Osmosis (d) Imbibition *(AIIMS 2012)*

122. The microscope usually used for seeing living cells or tissues is:
(a) Compound microscope (b) Electron microscope
(c) Phase contrast microscope (d) Light microscope *(AIIMS 2012)*

123. Which of the following is present both in prokaryotic and eukaryotic cells?
(a) Mitochondria (b) Endoplasmic reticulum (c) Ribosomes (d) Nucleus *(AFMC 2012)*

124. Extranuclear DNA in the cytoplasm is found inside:
(a) Golgi bodies (b) Lysosomes (c) Vacuoles (d) Mitochondria *AFMC 2012)*

125. Proteins required for functioning of nucleus are formed in:
(a) Nucleolus (b) RER (c) Cytoplasm (d) Mitochondria *(BHU 2012)*

126. Which of the following organelles is called suicidal bag of cell?
(a) Lysosome (b) Mitochondria (c) Peroxisome (d) Glycocalyx *(BHU 2012)*

127. Lysosomes have acidic environment inside their vesicles due to:
(a) Production of carboxylate ions inside it (b) Production of phosphate ions inside it
(c) High pH compared to outside (d) None of the above *(BHU 2012)*

128. Polytene chromosomes were discovered in:
(a) *Chironomus* (b) *Drosophila* (c) *Neurospora* (d) *Rattus* *(BHU 2012)*

129. Which of the following is the site of translation of the mRNA?
(a) Nucleus (b) Nucleolus (c) Golgi body (d) Ribosomes *(J&K CET 2012)*

130. The plane of cell wall formation in a dividing cell is determined by:
(a) Golgi apparatus (b) Microfilaments (c) Microtubules (d) Endoplasmic reticulum *(J&K CET 2012)*

131. From the following statements, select the statement that is true:
(a) All cells have cell wall
(b) Animal cells contain microtubules but plant cells do not
(c) Golgi apparatus is found only in animal cells
(d) Chloroplasts are found in plant cells but not in prokaryotic or animal cells *(J&K CET 2012)*

132. The cell membranes of the adjacent cells are fused at:
(a) Macula adherens (b) Zonula adherens (c) Zonula occulodens (d) Nexus *(AMU 2012)*

133. The usual axonemal arrangement of microtubules is:
(a) 6 pairs of doublets radially arranged at periphery with a pair of centrally located microtubules
(b) 6 pairs of doublets radially arranged at periphery with a single centrally located microtubule
(c) 9 pairs of doublets radially arranged at periphery with a pair of centrally located microtubules
(d) 9 pairs of doublets radially arranged at periphery with a single centrally arranged microtubule *(AMU 2012)*

134. When the chromosome has a centromere near to one end of chromosome resulting one shorter and one longer arm. Chromosome is called:
(a) Metacentric (b) Submetacentric (c) Acrocentric (d) Telocentric *(AMU 2012)*

135. The shape of cocci bacteria is:
(a) Rod-shaped (b) Spherical (c) Comma-shaped (d) Spiral *(AMU 2012)*

136. Which of the following is seen only in prokaryotic cells?
(a) Dictyosome (b) Ribosomes (c) Mesosomes (d) Endoplasmic reticulum
(e) DNA *(Kerala PMT 2012)*

137. The cytoplasm of neighbouring cells is connected with the help of:
(a) Middle lamella (b) Primary wall (c) Mitochondria (d) Endomembrane system
(e) Plasmodesmata *(Kerala PMT 2012)*

138. Choose the wrong statements regarding bacterial cell:
(A) Glycocalyx is the outermost envelope in bacteria
(B) The glycocalyx may be a loose sheath called capsule
(C) The glycocalyx may be thick and tough called slime layer
(D) A special structure formed by the plasma membrane is called mesosome
(E) Small bristle-like fibrils sprouting out of the cell are called fimbriae
(a) A and C are wrong (b) A and E are wrong (c) B and C are wrong (d) A and D are wrong
(e) C and D are wrong *(Kerala PMT 2012)*

139. Consider the following statements:
(A) In prokaryotic cells, a special membranous structure formed by extension of the plasma membrane into the cell is known as polysome
(B) The smooth endoplasmic reticulum is the major site for synthesis of glycoproteins
(C) Rubisco is the most abundant protein in the whole of the biosphere
(D) Mitochondria, chloroplasts and peroxisomes are not considered as part of endomembrane system
Of the above statements:
(a) C and D alone are correct (b) A and B alone are correct
(c) B and C alone are correct (d) A and D alone are correct
(e) B and D alone are correct *(Kerala PMT 2012)*

140. Consider the following statements with reference to facilitated transport:
(A) Requires ATP energy (B) Transport saturates
(C) Highly selective (D) Requires special membrane proteins
(E) Uphill transport
Of the above statements:
(a) A, B and C are relevant but D and E are irrelevant (b) B, C and E are relevant but A and D are irrelevant
(c) C, D and E are relevant but A and B are irrelevant (d) A, D and E are relevant but B and C are irrelevant
(e) B, C and D are relevant but A and E are irrelevant *(Kerala PMT 2012)*

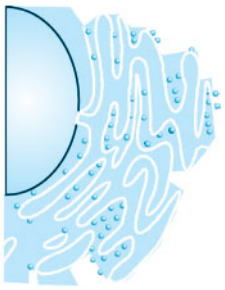
141. Pigment-containing membranous extensions in some cyanobacteria are:
(a) Heterocysts (b) Basal bodies (c) Pneumatophores (d) Chromotophores *(NEET 2013)*

142. A major site for lipid synthesis is:
(a) RER (b) SER (c) Symplast (d) Nucleoplasm *(NEET 2013)*

143. The Golgi complex plays a major role:
(a) In trapping the light and transforming it into chemical energy
(b) In digesting proteins and carbohydrates

(c) As energy trasnferring organalle
(d) In post-translational modification of proteins and glycosidation of lipids *(NEET 2013)*

144. Which one of the following organelle in the figure correctly matches with its function?



(a) Rough endoplasmic reticulum, formation of glycoproteins
(b) Golgi apparatus, protein synthesis
(c) Golgi apparatus, formation of glycolipids
(d) Rough endoplasmic reticulums, protein synthesis.

145. The fluid mosaic model of cell membrane was given by: *(AMU 2013)*
(a) S.S. Singer and G.L. Nicolson
(b) S. J. Singer and H.L. Nicolson
(c) S. J. Singer and G.L. Nicolson
(d) S. S. Singer and H.L. Nicolson

146. The movement of cilia and flagella is due to presence of: *(AMU 2013)*
(a) Radial spokes (b) Central sheath
(c) Singlet microtubles (d) Dyneins

147. The motile bacteria are able to move by:
(a) Cilia (b) Pili (c) Fimbriae (d) Flagella *(AIPMT 2014)*

148. Fructose is absorbed into blood through mucosal cells of intestine by the process called :
(a) Simple diffusion (b) Co-transport mechanism (c) Active transport (d) Facilitated transport *(AIPMT 2014)*

149. Match the following and select the correct answer:

1. Centriole	**(i)** Infoldings in mitochondria
2. Chlorophyll	**(ii)** Thylakoids
3. Cristae	**(iii)** Nucleic acids
4. Ribozymes	**(iv)** Basal body, cilia or flagella

(a) 1 (i) 2 (iii) 3 (ii) 4 (iv) (b) 1 (iv) 2 (iii) 3 (i) 4 (ii)
(c) 1 (iv) 2 (ii) 3 (i) 4 (iii) (c) 1 (i) 2 (ii) 3 (iv) 4 (iii) *(AIPMT 2014)*

150. The osmotic expansion of cell kept in water is chiefly regulated by:
(a) Plastid (b) Ribosomes (c) Mitochondria (d) Vacuoles *(AIPMT 2014)*

151. The solid linear cytoskeletal elements having a diameter of 6 nm and made up of a single type of monomer are known as:
(a) Intermediate filaments (b) Lamins (c) Microtubules (d) Microfilaments *(AIPMT 2014)*

152. Which structures perform the function of mitochondria in bacteria?
(a) Cell wall (b) Mesosomes (c) Nucleoid (d) Ribosomes *(AIPMT 2014)*

153. The structures that are formed by stacking of organized flattened membranous sacs in the chloroplasts are:
(a) Cristae (b) Grana (c) Stromal lamellae (d) Stroma *(AIMPT 2015)*

154. The chromosomes in which centromere is situated close to one end are:
(a) Metacentric (b) Acrocentric (c) Telocentric (d) Sub-metacentric *(AIMPT 2015)*

155. Select the correct matching in the following pairs:
(a) Smooth ER = oxidation of phospholipids (b) Smooth ER = Synthesis of lipids
(c) Rought ER = synthesis of glycogen (d) Rough ER = oxidation of fatty acids *(AIMPT 2015)*

156. True nucleus is absent in:
(a) *Anabaena* (b) *Mucor* (c) *Vaucheria* (d) *Volvox* *(AIMPT 2015)*

157. Which one of the following is not an inclusion body found in prokaryotes?
(a) Phosphate granule (b) Cyanophycean granule (c) Glycogen granule (d) Polysome *(AIMPT 2015)*

158. DNA is not present in :
(a) Chloroplast (b) Ribosomes (c) Nucleus (d) Mitochondria *(AIMPT 2015)*

159. Nuclear envelope is a derivative of :
(a) SER (b) Membrane of Golgi complex
(c) Microtubules (d) RER *(AIMPT 2015)*

160. Balbiani rings are sites of :
(a) Lipid synthesis (b) Nucleotide synthesis
(c) Polysaccharide synthesis (d) RNA and protein synthesis *(Re-AIMPT 2015)*

161. In angiosperms, microsporogenesis and megasporogenesis:
(a) occur in anther
(b) Form gametes without further divisions.
(c) Involve meiosis
(d) Occur in ovule *(Re-AIMPT 2015)*

162. Which of the following are not membrane-bound?
(a) Vacuoles (b) Ribosomes (c) Lysosomes (d) Mesosomes *(Re-AIMPT 2015)*

163. The function of the gap junction is to:
(a) Performing cementing to keep neighbouring cells together.
(b) Facilitate communication between adjoiing cells by connecting the cytoplasm for rapid movement of ions, small molecules and some large molecules.
(c) Separate two cells from each other
(d) Stop leaking of substance across a tissue *(Re-AIMPT 2015)*

164. The structures that help some bacteria to attach to rocks and/or host tissues are:
(a) Rhizoids (b) Fimbriae (c) Mesosomes (d) Hold fast *(Re-AIMPT 2015)*

165. In photosynthesis, the light independent reactions take place at :
(a) Thylakoid lumen (b) Photosystem-I (c) Photosystem-II (d) Stromal matrix *(Re-AIMPT 2015)*

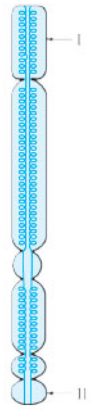
166. Cellular organelles with membranes are :
(a) Nuclei, ribosomes and mitochondria
(b) Chromosomes, ribosomes and ER
(c) ER, ribosomes and nuclei
(d) Lysosomes, Golgi apparatus and mitochondria *(Re-AIMPT 2015)*

167. Which of the below mentioned properties is not true with respect to facilitated transport?
(a) Requires special membrane proteins
(b) Transport saturates
(c) Uphill transport
(d) Highly selective *(KCET 2015)*

168. Which of the below mentioned structures does not form a part of the endomembrane system?
(a) Golgi complex (b) ER (c) Mitochondria (d) Vacuoles *(KCET 2015)*

169. Chloroplasts in higher plants are _____ shaped :
(a) Kidney (b) Lens (c) Bean (d) Dome *(MH-CET 2015)*

170. In the given diagram I and II indicate



(a) Chromomere and chromonemata
(b) Centromere and secondary constriction
(c) Secondary construction and satellite
(d) Telomere and satellite *(MH-CET 2015)*

171. (i) They help in respiration
(ii) They help in cell wall formation
(iii) They help in DNA replication
(iv)They increase surface area of plasma membrane.
Which of the following prokaryotic structure has all the above roles?
(a) Chromosomes (b) Ribosomes (c) Mesosomes (d) Lysosome
(e) Polysome *(Kerala PMT 2015)*

172. A cell organelle containing hydrolytic enzymes is:
(a) Mesosome (b) Lysosome (c) Microsome (d) Ribosome *(NEET (Phase-II) 2016)*

173. Which of the following r-RNA acts as structural RNA as well as ribozyme in bacteria?
(a) 5.8S r-RNA (b) 5S r-RNA (c) 18S r-RNA (d) 23S -rRNA *(NEET (Phase-II) 2016)*

174. Mitochondria and chloroplasts are:
1. Semi-autonomous organelles
2. Formed by division of pre-existing organelles as they contain DNA but lack protein-synthesizing machinery
(a) Both (1) and (2) are false
(b) Both (1) and (2) are correct
(c) (2) is true but (1) is false
(d) (1) is true but (2) is false *(NEET (Phase-I) 2016)*

175. Water soluble pigments found in plant cell vacuoles are:
(a) Anthocyanins (b) Xanthophylls (c) Chlorophylls (d) Carotenoids
(NEET (Phase-I) 2016)

176. Which of the following is not a feature of plasmids?
(a) Single stranded (b) Independent replication (c) Circular structure (d) Transferable
(NEET (Phase-I) 2016)

177. A complex of ribosomes attached to single strand of RNA is known as:
(a) Okazaki fragment (b) Polysome (c) Polymer (d) Polypeptide
(NEET (Phase-I) 2016)

178. Microtubules are the constituents of
(a) Centrosome, nucleosome and centrioles (b) Cilia, flagella and peroxisomes
(c) Spindle fibres, centrioles and cilia (d) Centrioles, spindle fibres and chromatin
(NEET (Phase-I) 2016)

179. Which one of the following cell organelles is enclosed by a single membrane?
(a) Nuclei (b) Mitochondria (c) Chloroplasts (d) Lysosomes
(NEET (Phase-I) 2016)

180. Which among the following are the smallest cells known without a definite cell wall, pathogens to plants as well as animals and can survive without oxygen ?
(a) *Bacillus* (b) *Pseudomonas* (c) *Mycoplasma* (d) *Nostoc* *(NEET 2017)*

181. Which of the following cell organelles is responsible for extracting energy from carbohydrates to form ATP ?
(a) Lysosome (b) Ribosome (c) Chloroplast (d) Mitochondrion *(NEET 2017)*

182. Which of the following RNAs should be most abundant in animal cells ?
(a) r-RNA (b) t-RNA (c) m-RNA (d) mt-DNA *(NEET 2017)*

183. Golgi complex participates in:
(a) Fatty acid breakdown (b) Respiration in bacteria
(c) Formation of secretory vesicles (d) Activation of amino acids *(NEET 2018)*

184. Which of the following is true for nucleolus?
(a) Larger nucleoli are present in dividing cells (b) It takes part in spindle formation
(c) It is a membrane-bound structure (d) It is a site for active ribosomal RNA Synthesis
(NEET 2018)

185. Which of the following events does not occur in rough endoplasmic reticulum?
(a) Protein folding (b) Cleavage of signal peptide
(c) Protein glycosylation (d) Phospholipid synthesis *(NEET 2018)*

186. Select the incorrect match:
(a) Lampbrush chromosomes : Diplotene bivalents
(b) Submetacentric chromosomes : L-shaped chromosomes
(c) Allosomes : Sex chromosomes
(d) Polytene chromosomes : Oocytes of amphibians *(NEET 2018)*

187. Many ribosomes may associate with a single m-RNA to form multiple copies of polypeptide simultaneously. Such strings of ribosomes are termed:
(a) Polysomes (b) Plastidomes (c) Polyhedral bodies (d) Nucleosomes *(NEET 2018)*

ANSWERS

1. (a);	**2.** (b);	**3.** (c);	**4.** (a);	**5.** (a);	**6.** (d);	**7.** (b);	**8.** (d);	**9.** (b);	**10.** (b);
11. (d);	**12.** (a);	**13.** (a);	**14.** (b);	**15.** (d);	**16.** (a);	**17.** (b);	**18.** (d);	**19.** (a);	**20.** (e);
21. (a);	**22.** (b);	**23.** (a);	**24.** (c);	**25.** (a);	**26.** (c);	**27.** (b);	**28.** (b);	**29.** (a);	**30.** (c);
31. (b);	**32.** (c);	**33.** (a);	**34.** (a);	**35.** (b);	**36.** (a);	**37.** (c);	**38.** (d);	**39.** (b);	**40.** (d);
41. (c);	**42.** (d);	**43.** (d);	**44.** (a);	**45.** (d);	**46.** (b);	**47.** (c);	**48.** (b);	**49.** (a);	**50.** (c);
51. (b);	**52.** (c);	**53.** (c);	**54.** (d);	**55.** (d);	**56.** (b);	**57.** (c);	**58.** (d);	**59.** (d);	**60.** (d);
61. (a);	**62.** (b);	**63.** (a);	**64.** (b);	**65.** (d);	**66.** (b);	**67.** (a);	**68.** (b);	**69.** (a);	**70.** (a);
71. (c);	**72.** (a);	**73.** (a);	**74.** (a);	**75.** (a).	**76.** (b);	**77.** (d);	**78.** (d);	**79.** (a);	**80.** (b);
81. (c);	**82.** (b);	**83.** (c);	**84.** (d);	**85.** (a);	**86.** (c);	**87.** (b);	**88.** (a);	**89.** (d);	**90.** (b);
91. (e);	**92.** (c);	**93.** (c);	**94.** (d);	**95.** (c);	**96.** (d);	**97.** (d);	**98.** (d);	**99.** (b);	**100.** (c);
101. (c);	**102.** (b);	**103.** (d);	**104.** (c);	**105.** (a);	**106.** (b);	**107.** (c);	**108.** (a);	**109.** (a);	**110.** (c);
111. (a);	**112.** (b);	**113.** (b);	**114.** (a);	**115.** (b);	**116.** (c);	**117.** (c);	**118.** (b);	**119.** (d);	**120.** (d);
121. (b);	**122.** (c);	**123.** (c);	**124.** (d);	**125.** (c);	**126.** (a);	**127.** (d);	**128.** (a);	**129.** (d);	**130.** (c);
131. (d);	**132.** (c);	**133.** (c);	**134.** (c);	**135.** (b);	**136.** (c);	**137.** (e);	**138.** (c);	**139.** (a);	**140.** (e);
141. (d);	**142.** (b);	**143.** (d);	**144.** (d);	**145.** (c);	**146.** (d);	**147.** (d);	**148.** (d);	**149.** (c);	**150.** (d);

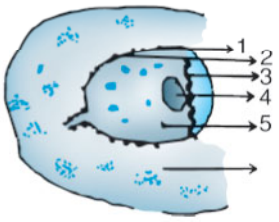
151. (d);	**152.** (b);	**153.** (b);	**154.** (b);	**155.** (b);	**156.** (a);	**157.** (d);	**158.** (b);	**159.** (d);	**160.** (d);
161. (c);	**162.** (b);	**163.** (b);	**164.** (b);	**165.** (d);	**166.** (d);	**167.** (c);	**168.** (c);	**169.** (b);	**170.** (d);
171. (c);	**172.** (b);	**173.** (d);	**174.** (d);	**175.** (a);	**176.** (a);	**177.** (b);	**178.** (c);	**179.** (d);	**180.** (c);
181. (d);	**182.** (a);	**183.** (c);	**184.** (d);	**185.** (d);	**186.** (d);	**187.** (a).			

HINTS OF SOME DIFFICULT MULTIPLE CHOICE QUESTIONS

10. (b); Ribosome is naked (without any unit membranous covering) so is called subcellular organelle.
21. (a); Amyloplasts are starch-storing plastids and not protein storing.
39. (b); In mitochondria of cells of germinating seeds, the fatty acids undergo β-oxidation to produce acetyl co-A. molecules which enter Kreb's cycle.
54. (d); Endomembrane system is formed of certain cell organelles like ER,Golgi complex, lysosomes and vacuoles which work in coordination.
81. (c); Because contractile vacuole is used to expel excess of water which enter in the body of fresh-water protozoans (e.g. *Paramecium*) due to endosmosis. It is lost in marine water due to isotonic medium.
102. (b); Golgi body is organelle involved in glycosylation of proteins and lipids to form glycoproteins and glycolipids respectively.
127. (d); Acidic nature of matrix of lysosomes is due to high proton concentration as the proton pump present in its unit membrane pumps the protons inside the lysosome.
148. (d); Because fructose is absorbed along its concentration gradient with the help of certain fructose specific carrier proteinaceous molecules.
156. (a); Because *Anabaena* is a prokaryotic cyanobacterial cell.
173. (d); 23S r-RNA is the structural component of 50S (larger) subunit of 70S bacterial ribosome. Its domain V is with activity of the enzyme peptidyl transferase.

B. CBSE - PMT (MAIN EXAMINATION) QUESTIONS :

1. (a) Label the parts of interphase nucleus (1, 2, 5, 6).
(b) Write the function of 3 and 4.



(CBSE 2004)

Ans. (*a*) **1.** Nuclear pore; **2.** Nuclear membrane; **3.** Chromatin fibre; **4.** Nucleolus; **5.** Nucleoplasm; **6.** Cytoplasm.
(*b*) **(i) Chromatin fibres :** These are formed of DNA and associated proteins. DNA acts as genetic material and helps in heredity.
(ii) Nucleolus : It is site of formation of rRNA which participates in the formation of ribosomes and protein synthesis. It also helps in cell division.

2. Match the Column I with Column II (at least ten)

I	II
(i) Centromere	(a) Small DNA fragments formed during DNA replication
(ii) Kinetochore	(b) Breaking of DNA at specific site
(iii) Telomere	(c) Major protein of chromatin
(iv) Exon	(d) Sub-unit of chromatin
(v) Intron	(e) Highly condensed, non-transcribing part of chromosome
(vi) Heterochromatin	(f) Non-coding sequence of eukaryotic chromosome
(vii) Nucleosome	(g) Sister chromatids attached to a point at interphase
(viii) Histone	(h) Protein helps in binding with microtubules
(ix) Toposisomerase	(i) Which seals ends of chromosomes
(x) Okazaki fragments	(j) Coding sequence of eukaryotic chromosome
(xi) Operon reading frame	(k) Functional gene

(CBSE 2004)

Ans. (i) (g); (ii) (h); (iii) (i); (iv) (j); (v) (f); (vi) (e); (vii) (d); (viii) (c); (ix) (b); (x) (a); (xi) (k).

3. Fill in the blanks :
(i) Biomembrane consists of phospholipids which has one unit of _____ and two units of _____ and phosphate group.

(ii) **Most of food stored in the higher plants is in the form of _____ but their cell wall is formed of _____ .** (*CBSE 2006*)

Ans. (i) Glycerol (polar head), Fatty acids (non-polar tails)
(ii) Starch, cellulose.

4. Write the function of the following :
(a) Microtubules (b) Sphaerosome (c) Endodermis
(d) Companion cells (e) Lenticles (*CBSE 2006*)

Ans. (a) **Microtubules** help in cell division, organisation of intracellular structures, intracellular transport, and ciliary and flagellar motility.
(b) **Sphaerosomes** are involved in synthesis and storage of lipids.
(c) **Endodermis** forms the outer boundary of the stele (vascular tissues) of the stem; stores the starch grains and allows the solutions to pass through from the vascular bundles to the cortex.
(d) **Companion cells** control the functioning of adjacent sieve cells of phloem.
(e) **Lenticles** of bark allow the exchange of oxygen and carbon dioxide, and also help in transpiration.

5. What is a nucleosome? How many base pairs are present in a typical nucleosome? (*CBSE 2008*)

Ans. Nucleosome is a subunit of chromatin. It is an octomer of four types of histones (2 molecules each of H_2A, H_2B, H_3 and H_4) called ***nu* body**. It is made up of a core of eight histone molecules wrapped by double helical DNA formed of about 200 base pairs. DNA takes $1\frac{3}{4}$ turns around the protein core.

6. Fill in the blanks :
Golgi body, associated to RER, if separated away, will not form ..... (*CBSE 2008*)

Ans. Glycoproteins.

7. How do the following help in transfer, storage and expression of genetic informations?
(a) Centriole **(b)** Centromere **(c)** Nucleolus
(d) Ribosomes **(e)** Chromatin (*CBSE 2009*)

Ans. (a) Centriole takes part in spindle formation during cell division.
(b) Centromere helps in attachment of chromosomes to the spindle fibres and splits into two to form chromatids during anaphase stage.
(c) Ribosomal proteins are synthesized in nucleolus and are essential for protein synthesis.
(d) Ribosome is the site of protein synthesis.
(e) Genetic informations are mainly stored in chromatin.

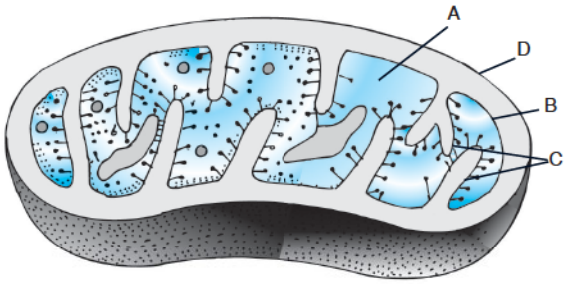
8. In mitochondria, protons accumulate in the :
(a) Intermembrane space (b) Matrix (c) Outer membrane (d) Inner membrane (*CBSE 2011*)

Ans. (a).

9. Which one of the following is not considered as a part of the endomembrane :
(a) Vacuole (b) Lysosome (c) Golgi complex (d) Peroxisome (*CBSE 2011*)

Ans. (d).

10. The figure below shows the structure of a mitochondrion with its four parts labelled (A), (B), (C) and (D). Select the part correctly matched with its function.



(a) Part (C) : Cristae – Possess circular DNA molecule and ribosomes
(b) Part (A) : Matrix – Major site for respiratory chain enzymes
(c) Part (D) : Outer membrane – Give rise to inner membrane by splitting
(d) Part (B) : Inner membrane – Forms infoldings called cristae (*CBSE 2011*)

Ans. (d).

11. Which one of the following structures is an organelle within an organelle?
(a) Ribosome (b) Peroxisome (c) ER (d) Mesosome (*CBSE 2012*)

Ans. (a).

12. Which one of the following cellular parts is correctly described?
(a) Thylakoids—flattened membranous sacs forming the grana of chloroplasts
(b) Centrioles—sites for active RNA synthesis

(c) Ribosomes—those of chloroplasts are larger (80S) while those of the cytoplasm are smaller (70S)
(d) Lysosomes—optimally active at a pH of about 8.5 *(CBSE 2012)*

Ans. (a).

C. MATCHING TYPE QUESTIONS :

1. Match column-I with column-II and select the correct option :

Column-I	Column-II
A. SER	1. Help in movement of chromosomes during cell division
B. Chromoplasts	2. Synthesis of glycogen
C. Microtubules	3. Formation of ribosomes
D. Nucleolus	4. Provide colour to flower and help in pollination

(a) A (ii), B (iii), C (i), D (iv) (b) A (i), B (iv), C (ii), D (iii)
(c) A (iii), B (iv), C (i), D (ii) (d) A (ii), B (iv), C (i), D (iii)

2. Match the items in Column–I with Column-II and choose the correct answer :

Column-I	Column-II
A. Sap vacuole	1. Contain digestive enzymes
B. Contractile vacuole	2. Store metabolic gases
C. Food vacuole	3. Osmoregulation
D. Air vacuole	4. Store lipids
E. Sphaerosomes	5. Store and concentrate mineral salts and nutrients

(a) A = 5, B = 3, C = 1, D = 2, E = 4 (b) A = 2, B = 3, C = 4, D = 5, E = 1
(c) A = 5, B = 2, C = 3, D = 1, E = 4 (d) A = 5, B = 3, C = 2, D = 4, E = 1
(e) A = 4, B = 1, C = 3, D = 5, E = 2 *(Kerala PMT 2006)*

3. Match the following with correct combinations :

Column-I	Column-II
A. Endoplasmic reticulum	1. Stack of cisternae
B. Spherosomes	2. Store oil or fats
C. Dictyosomes	3. Synthesis and storage of fats
D. Peroxisomes	4. Photorespiration
E. Elaioplasts	5. Detoxification of drugs

(a) A = 5, B = 3, C = 1, D = 4, E = 2 (b) A = 5, B = 3, C = 2, D = 4, E = 1
(c) A = 2, B = 3, C = 1,s D = 4, E = 5 (d) A = 3, B = 4, C = 1, D = 5, E = 2
(e) A = 3, B = 5, C = 1, D = 4, E = 2 *(Kerala PMT 2008)*

4. Match the columns and identify the correct option :

Column I	Column II
A. Thylakoids	(i) Disc-shaped sacs in Golgi apparatus
B. Cristae	(ii) Condensed part of DNA
C. Cisternae	(iii) Flat membranous sacs in stroma
D. Chromatin	(iv) Infolds in mitochondria

(a) A (iv) B (iii) C(i) D (ii) (b) A (iii) B (iv) C (i) D (ii)
(c) A (iii) B (i) C (iv) D (ii) (d) A (iii) B (iv) C (ii) D (i) *(Re-AIPMT PMT 2015)*

5. Match the column-I with that of column-II and choose the correct combination from the options given :

Column-I	Column-II
A. Rough ER	(i) Synthesis of glycoproteins
B. Smooth ER	(ii) Aerobic respiration
C. Mitochondria	(iii) Synthesis of lipids
D. Golgi apparatus	(iv) Protein synthesis

(a) A (i) B (ii) C (iii) D (iv) (b) A (ii) B (iii) C (iv) D (i)
(b) A (iii) B (iv) C (ii) D (i) (d) A (iv) B (iii) C (ii) D (i)
(e) A (iv) B (iii) C (i) D (ii). *(Kerala PMT 2015)*

ANSWERS

1. (*d*); 2. (*a*); 3. (*a*); 4. (*b*); 5. (*d*).

D. ASSERTION TYPE QUESTIONS :

The following questions consist of two statements each, printed as *Assertion* and *Reason*. While answering these questions you are required to choose any one of the following four responses :

A. If both *Assertion* and *Reason* are true and *Reason* is correct explanation of *Assertion*.
B. If both *Assertion* and *Reason* are true and *Reason* is not correct explanation of *Assertion*.
C. If *Assertion* is true but *Reason* is false.
D. If both *Assertion* and *Reason* are false.

1. **Assertion :** Highest state of entropy in the living system is at death.
Reason : Free energy is required to prevent death.
A **B** **C** **D**

2. **Assertion :** A fully turgid cells is called plasmolysed.
Reason : Plasmolysis involves endosmosis of water.
A **B** **C** **D**

3. **Assertion :** Fluidity of plasma membrane is due to presence of phospholipids.
Reason : Fatty acids of the phospholipids have kinks which do not allow the packing of molecules.
A **B** **C** **D**

4. **Assertion :** Active transport is a vital process.
Reason : Active transport is inhibited by low temperature and presence of cyanides.
A **B** **C** **D**

5. **Assertion :** Depolarization is an active process.
Reason : In depolarization, Na^+ ions move from lower concentration to higher concentration.
A **B** **C** **D**

6. **Assertion :** Passive processes like diffusion and osmosis do not require energy.
Reason : Because the plasma membrane is a static membrane.
A **B** **C** **D**

7. **Assertion :** Cyanobacteria are photosynthetic blue green algae with all the prokaryotic structures.
Reason : They are green due to presence of chloroplasts.
A **B** **C** (*AIIMS 2000*)

8. **Assertion :** Specialisation of cells is advantageous to organisms.
Reason : It increases orperational efficiency.
A **B** **C** **D** (*AIIMS 2002*)

9. **Assertion :** The number of cells in a multicellular organism is inversely proportional to body size.
Reason : All the cells in the biological world are of same size.
A **B** **C** **D** (*AIIMS 2002*)

10. **Assertion :** It is important that organisms have cells.
Reason : A cell keeps its chemical composition steady within its boundary.
A **B** **C** **D** (*AIIMS 2002*)

11. **Assertion :** A cell membrane shows fluid behaviour.
Reason : A membrane is a mosaic or composite of diverse lipids and proteins.
A **B** **C** **D** (*AIIMS 2003*)

12. **Assertion :** Mitochondria and chloroplasts are semi-autonomous organelles.
Reason : They are formed by division of pre-existing organelles and contain DNA but lack protein synthesizing machinery.
A **B** **C** **D** (*AIIMS 2005*)

13. **Assertion :** Polytene chromosomes have a high amount of DNA.
Reason : Polytene chromosomes are formed by repeated replication of chromosomal DNA without separation of chromatids.
A **B** **C** **D** (*AIIMS 2006*)

14. **Assertion :** Eukaryotic cells have the ability to adopt a variety of shapes and carry out directed movements.
Reason : There are three principal types of protein filaments–microfilaments, microtubules and intermediate filaments which constitute the cytoskeleton.
A **B** **C** **D** (*AIIMS 2006*)

15. **Assertion :** A cell membrane shows fluidly behaviour.
Reason : A cell membrane is a mosaic or composite of diverse lipids and proteins.
A **B** **C** **D** (*AIIMS 2008*)

ANSWERS

1. (B);	**2.** (D);	**3.** (A);	**4.** (A);	**5.** (D);	**6.** (C);	**7.** (C);	**8.** (A);	**9.** (D);	**10.** (B);
11. (B);	**12.** (C);	**13.** (A);	**14.** (B);	**15.** (B).					

E. ADDITIONAL MULTIPLE CHOICE QUESTIONS :

1. The main organelle involved in modification and routing of newly synthesized proteins to their destinations is :
(a) Mitochondria (b) Endoplasmic reticulum
(c) Lysosome (d) Chloroplast

2. Chlorophyll in chloroplasts is located in :
(a) Grana (b) Pyrenoid (c) Stroma (d) Both grana and stroma

3. According to fluid mosaic model, cell membranes are semi-fluid, where lipids and integral proteins can diffuse randomly. In recent years, this model has been modified. In this regard, which of the following statements is incorrect?
(a) Proteins can travel within the lipid bilayer
(b) Proteins can remain confined within certain domains of membrane
(c) Proteins can also undergo flip-flop movements in lipid bilayer
(d) Many proteins remain completely embedded within lipid bilayer

4. Centromere is required for :
(a) Transcription (b) Crossing over
(c) Cytoplasmic cleavage (d) Movement of chromosomes towards poles

5. Which of the following is the simplest amino acid?
(a) Alanine (b) Asparagine (c) Glycine (d) Tyrosine

6. Chemiosmotic theory of ATP synthesis in the chloroplasts and mitochondria is based on :
(a) Membrane potential (b) Accumulation of Na^+–ions
(c) Accumulation of K^+–ions (d) Proton gradient

7. Many cells function properly and divide mitotically even though they do not have :
(a) Plasma membrane (b) Cytoskeleton (c) Mitochondria (d) Plastids

8. Which one of the following statements is wrong?
(a) Lysosomes are double membranous vesicles budded off from Golgi body and contain digestive enzymes
(b) ER consists of a network of tubules and helps in transport, synthesis and secretion
(c) Leucoplasts are bounded by two membranes, lack pigment but contain DNA and protein forming machinery
(d) Sphaerosomes are single membrane bound and help in synthesis and storage of lipids

9. In which of the following would you expect to find glyoxysomes?
(a) Endoplasm of wheat (b) Endoplasm of castor (c) Palisade cells of leaf (d) Root hairs

10. Main function of dictyosome is :
(a) Respiration (b) Storage (c) Secretion (d) Breakdown of fats

11. Which of the following is not a feature of prokaryote?
(a) Absence of nuclear membrane (b) DNA is associated with histones
(c) Absence of mitochondrion (d) Both (b) and (c)

12. Cell theory was given by :
(a) Robert Hooke (b) Robert Brown
(c) Schleiden and Schwann (d) Messelson and Stahl

13. Phagosomes and pinosomes collectively referred to as :
(a) Lysosomes (b) Glyoxysomes (c) Sphaerosomes (d) Endosomes

14. The crystals of calcium carbonate, which appear like a bunch of grapes in epidermal cells of the leaves of some plants, are called
(a) Sphaerosides (b) Raphides (c) Otoliths (d) Cystoliths

15. If a plant cell is placed in a solution less concentrated than that of cell sap, water from outside will enter into the protoplasm through the process of :
(a) Endosmosis (b) Diffusion (c) Imbibition (d) Plasmolysis

16. Ribosome :
(a) Consists of a large and two small subunits
(b) Contains identical components in prokaryote and eukaryote
(c) Is the site of only RNA replication
(d) Has two or three sites for t-RNAs

17. Racker's particles occur in :
(a) Chromosomes (b) Nucleus (c) Golgi complex (d) Mitochondria

18. The core metal of chlorophyll is :
(a) Fe (b) Cu (c) Ni (d) Mg

19. A single unit membrane surrounds the organelle :
(a) Lysosome (b) Nucleus (c) Microsome (d) Chloroplast

20. The membrane around the vacuole is called :
(a) Tonoplast (b) Cytoplast (c) Leucoplast (d) Amyloplast

21. What is formula of chlorophyll "a"?
(a) $C_{55}H_{72}O_5N_4Mg$ (b) $C_{55}H_{70}O_6N_4Mg$ (c) $C_{35}H_{32}O_5N_4Mg$ (d) $C_{54}H_{70}O_6N_4Mg$

22. Cell membrane is :
(a) Semipermeable (b) Permeable (c) Selectively permeable (d) Impermeable

23. Which of the following is characteristic of phospholipids of plasma membrane?
(a) One non-polar head and two polar tails
(b) One polar head and two non-polar tails
(c) Two non-polar heads and one polar tail
(d) Two polar heads and one non-polar tail
(e) Two polar heads and two polar tails

24. The organelle associated with aerobic respiration is :
(a) Nucleus (b) Centriole (c) Chloroplast (d) Mitochondria

25. Plasma membrane helps in :
(a) Osmoregulation
(b) Protein synthesis
(c) Nucleic acid synthesis
(d) Transportation of only water in and out of cell

26. Which of the following organelles does not have membrane?
(a) Ribosome (b) Nucleus (c) Chloroplast (d) Mitochondria

27. Centrioles take part in formation of :
(a) Cell plate (b) Spindle (c) Nucleolus (d) Start of cell division

28. Phytol chain is present in :
(a) Carotenoids (b) Chlorophyll (c) Haemoglobin (d) Phycocyanin

29. Amyloplasts are particles storing :
(a) Starch (b) Proteins (c) Fats (d) All of these

30. Element necessary for middle lamella is :
(a) Ca (b) K (c) Cu (d) Zn

ANSWERS

1. (b);	**2.** (a);	**3.** (d);	**4.** (d);	**5.** (c);	**6.** (d);	**7.** (d);	**8.** (a);	**9.** (b);	**10.** (c);
11. (b);	**12.** (c);	**13.** (d);	**14.** (d);	**15.** (a);	**16.** (d);	**17.** (d);	**18.** (d);	**19.** (a);	**20.** (a);
21. (a);	**22.** (c);	**23.** (b);	**24.** (d);	**25.** (a);	**26.** (a);	**27.** (b);	**28.** (b);	**29.** (a);	**50.** (a).

Chapter Practice Test

Time Allowed : 1:30 Hours *Maximum Marks : 35*

1. Who proposed cell theory? What is its objectionable postulate? (1)
2. Name the smallest sized cell and largest sized plant cell. (1)
3. What is facilitated diffusion? (1)
4. State one difference between cell organelles and cell inclusions. (1)
5. Enlist two functions of a plant vacuole. (1)
6. Write peculiar features of nucleoid of a bacterial cell. (2)
7. Differentiate between pinocytosis and phagocytosis. (2)
8. Enlist four functions of Endoplasmic reticulum. (2)
9. Why are lysosomes called suicidal bags? (2)
10. Differentiate between leucoplasts and chromoplasts. (2)
11. Describe the main postulates of fluid-mosaic model of plasma membrane with the help of a labelled diagram. (3)
12. Draw a neat and labelled diagram of a mitochondrion. Why it is called semiautonomous organelle? (3)
13. Describe the structure and functions of nucleolus. (3)
14. Draw T.S. of a centriole. Enlist its functions. (3)
15. Differentiate 70 S and 80 S types of ribosomes. (3)
16. (a) Draw a neat and labelled diagram of chloroplast.
    (b) Why thylakoids are called structural and functional elements of chloroplast? (5)

❑❑❑

To check your performance, see ANSWERS TO CHAPTER PRACTICE TEST at the end of Part I of the book.

CHAPTER 9

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INTRODUCTION

All the living organisms are essentially formed of numerous coordinated compartments called **cells.** Every cell is basically formed of 2 functional regions :

Plasma membrane and **protoplasm**

Protoplasm was called '**physical basis of life**' by **Huxley** while **Schultz** (1861) established the similarity between the protoplasm of plants and animals and proposed the "**protoplasm theory**". The ground substance of protoplasm, after removing all the major cell organelles and cell inclusions, is called **hyaloplasm** or **cytoplasmic matrix.** Basically the hyaloplasm is a complex **crystallo-colloidal system.** It consists of high water contents containing various compounds of biological importance, some of which are soluble in water e.g. glucose, amino acids, minerals, etc. while some of these are insoluble in it and are responsible for its colloidal nature. The collection of various types of biomolecules of a cell collectively form **cellular pool.** These biomolecules occur in **two forms :**

1. Inorganic compounds e.g. mineral salts and water.

2. Organic compounds e.g. carbohydrates, proteins, fats, nucleic acids, vitamins, enzymes, hormones, etc.

Organic and inorganic compounds in the cytoplasm generally occur in 9:1. Chemical analysis of these biomolecules revealed that protoplasm essentially consists of 25 types of elements which are divided into **three categories :**

1. Major elements. These include **six elements :** carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P) and Sulphur (S) which collectively form about 98% of weight of protoplasm and are also called **protoplasmic elements.**

2. Minor or Trace elements. These include Ca^{++}, Mg^{++}, Na^{+}, K^{+}, Cl^{-}, I^{-}, Fe^{++} etc. which collectively form only 2% of weight of protoplasm.

3. Ultra-trace elements. These include Mn^{++}, Co^{++}, Cu^{++}, Zn^{++}, Mo^{++}, Boron, Vanadium, etc. which collectively form 0.001% of the protoplasm.

The chemical analysis of earth's crust revealed that it also contains all those elements as reported in a sample of living tissue but having different relative abundance of carbon, hydrogen and other elements as shown in Table 1 :

Table 1. Relative abundance of different elements in human body and Earth's crust.

Element	Human body (% weight)	Earth's crust (% weight)
1. Hydrogen (H)	0.5	0.14
2. Carbon (C)	18.5	0.03
3. Oxygen (O)	65.0	46.6
4. Nitrogen (N)	3.3	Very little
5. Sulphur (S)	0.3	0.03
6. Sodium (Na)	0.2	2.8
7. Calcium (Ca)	1.5	3.6
8. Magnesium (Mg)	0.1	2.1
9. Silicon (Si)	Negligible	27.7

HOW TO ANALYSE CHEMICAL COMPOUNDS?

Organic compounds can be analysed by the following procedure :

1. Grind a living tissue (a piece of vegetable or liver) in trichloroacetic acid in a mortar with a pestle to obtain a thick slurry.

2. Filter this slurry of living tissue through a cheese cloth or cotton to obtain two fractions : **Filtrate** (acid-soluble pool) and **retentate** (acid-insoluble fraction). The acid soluble fraction represents the microbiomolecules of cytoplasm while acid insoluble fraction represents macrobiomolecules and organelles.

3. Each fraction is subjected to various fractionation techniques like **differential centrifugation** (to separate various sub-cellular structures like nuclei, mitochondria, etc.); **salting out** (by using high salt concentrations e.g. of ammonium sulphate); **dialysis** (to separate large sized proteins); **column chromatography** (to separate proteins due to differences of their charge, size, binding affinity, etc.); **ion-exchange chromatography** (due to different net electric charges of the compounds); **electrophoresis** (on the basis of migration of charged compounds in an electric field); etc.

4. Each fraction is then purified and then its chemical structure and molecular formula are determined by adopting different analytical techniques like **electrospray mass spectrometry.**

Inorganic elements and compounds can be analysed by the following procedure.

1. Weigh a small amount of a living tissue and note down its **wet weight.**

2. Dry the living tissue by evaporating its water in an oven and note down its **dry weight.**

3. Burn the dried tissue to oxidise all the organic compounds to obtain **ash** which contains inorganic compounds of calcium, magnesium, etc. Inorganic compounds like phosphates and sulphates are also found in acid-soluble fraction.

4. Ash or acid-soluble fraction is subjected to elemental analysis to know elemental composition of living tissues in the form of carbon, oxygen, hydrogen, chloride, sodium (Na^+), potassium (K^+), calcium (Ca^{++}), magnesium (Mg^{++}), inorganic compounds like NaCl, $CaCO_3$, phosphates (PO_4^{3-}), sulphates (SO_4^{2-}), etc.

BIOMICROMOLECULES

I. MONOSUGARS (MONOSACCHARIDES)

General structure. These are simplest type of carbohydrates formed of single aldehydic or ketonic derivatives of polyhydroxy alcohols. Chemically, these are formed of **C, H and O** generally in the ratio of **1 : 2 : 1.** General formula for monosaccharides is $C_n(H_2O)_n$ or $(CH_2O)_n$ where n is the number of C-atoms in a monosugar which varies from 3 to 7. Monosaccharides are called **sugars** as these are **sweeter** in taste.

Types of monosaccharides. On the **basis of number of C-atoms,** monosaccharides are divided into following categories :

1. Trioses (with 3-carbons)
General formula = $C_3H_6O_3$ e.g. **Glyceraldehyde, Dihydroxyacetone.**

2. Tetroses (with 4-carbons)
General formula = $C_4H_8O_4$ e.g. **Erythrose, Threose.**

3. Pentoses (with 5-carbons)
General formula = $C_5H_{10}O_5$ e.g. **Ribose, Deoxyribose, Xylose, Xylulose, Ribulose.**

4. Hexoses (with 6-carbons)
General formula = $C_6H_{12}O_6$ e.g. **Glucose, Mannose, Galactose** and **Fructose.**

5. Heptoses (with 7-carbons)
General formula = $C_7H_{14}O_7$ e.g. **Sedoheptulose.**

Two categories of Monosaccharides. On the basis of **nature of carbonyl group,** monosaccharides are divided into **two categories :**

1. Aldoses. These monosugars have **aldehydic group** at C-1′ e.g. **Glucose, Galactose.**

2. Ketoses. These monosugars have **ketonic group** at C-2′ e.g. **Fructose.**

Two Cyclic forms of monosaccharides (Fig. 1)

1. Furanoses. All the pentoses (e.g. Ribose, Deoxyribose) and Ketohexoses (e.g. Fructose) occur as a 5-membered ring form which resembles furan so called furanose ring e.g. **Ribose** and **Fructose.**

2. Pyranoses. Most of aldohexoses (e.g. **Glucose, Galactose** and **Mannose**) occur as 6-membered ring form which resembles pyran so called pyranose ring.

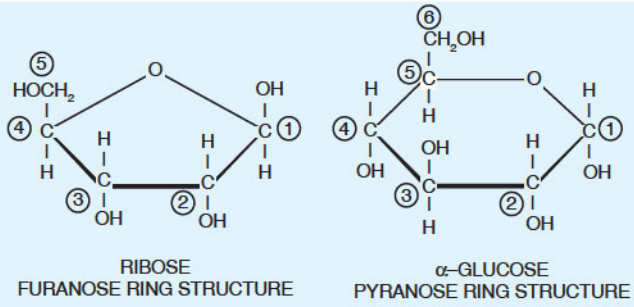


Fig. 1. Cyclic forms of monosaccharides.

Functions of monosaccharides

1. As respiratory fuel. Glucose acts as **chief respiratory fuel** because it is easily oxidisable and is present abundantly in the body fluids. It is also called **Carbohydrate currency** of the body. Physiological fuel value of glucose is **4.0 Kcal.** Glucose provides energy for about 60 per cent of energy needs of man. One glucose molecule produces about 38 ATP molecules (*i.e.*, 280 Kcal).

2. Ribose is the structural component of RNA, certain coenzymes like FAD and NAD, and certain energy molecules like ATP, GTP, etc.

3. Deoxyribose is the component of DNA.

4. Intermediates of C_3-cycle of photosynthesis e.g. Glyceraldehyde, Xylulose, Ribulose, Sedoheptulose, etc.

5. Galactose is the component of medullary sheath.

6. Monosaccharides act **as monomers** for formation of oligosaccharides like sucrose, maltose, etc. and polysaccharides like starch, glycogen, cellulose, etc.

7. When excess, monosugars can be changed into amino acids or fats.

8. Glucose **(grape sugar or blood sugar or dextrose)** and fructose **(fruit or sweetest sugar)** are reserve food of grapes and fruits respectively.

9. Ascorbic acid (Vitamin C) is a sugar acid and maintains capillary wall and helps in tyrosine metabolism.

II. OLIGOSACCHARIDES

Oligosaccharides are those carbohydrates which are formed of two to ten monosaccharides interlinked by **glycosidic bonds** formed by dehydration synthesis. Out of these, most important and smallest oligosaccharides are **disaccharides (double sugars)**.

Disaccharides. Disaccharides when treated with dilute acids, are hydrolysed to form free monosaccharide units. However, they are not hydrolysed by base.

$$C_{12}H_{22}O_{11} + H_2O \longrightarrow C_6H_{12}O_6 + C_6H_{12}O_6$$

Many disaccharides are found e.g.

(a) Maltose (b) Sucrose (c) Lactose.

(a) Maltose (Fig. 2). It is simplest of all disaccharides. It is made up of two units of glucose molecules interlinked by α(1→4) glycosidic bond. Its sweetening power is 32. It is a major product in enzymatic hydrolysis of starch. It is formed in germinating starchy seeds and malt. It is also called as **malt sugar.**

(b) Sucrose (Fig. 3). It is composed of α-D-glucose and β-D-fructose attached together by the aldehyde and ketone

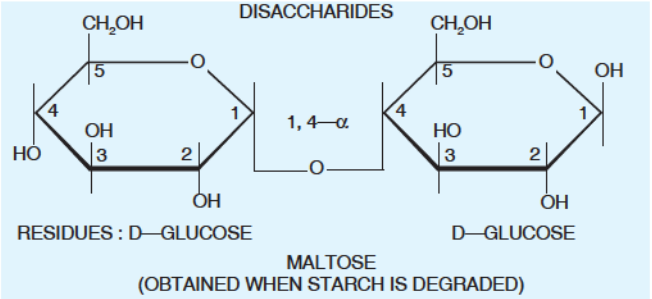


Fig. 2. Structure of maltose.

carbon by α(1→2) glycosidic bond. However, sucrose is not a reducing sugar as compared to maltose and lactose which are reducing ones. Sweetening power of

DID YOU KNOW?

- Carbohydrates constitute about 80% of dry weight of plants.
- In most of carbohydrates, H and O occur in 2 : 1 ratio as found in water.
- Trioses and tetroses occur only in open chain form.
- Pentoses, Hexoses and Heptoses occur in both open chain and cyclic form.
- Glucose occur in two forms : **α-and β-form.**
- **Laevulose :** Fructose found in nectar and honey.
- **Glycosidic bond :** Bond formed by dehydration synthesis between aldehydic or ketonic group of a sugar and alcoholic or amino group of another compound.
- Carbohydrates are commonly called **saccharides.**
- Glucose, Galactose, Mannose and Fructose are **isomers** of one another as have same molecular formula *i.e.* $C_6H_{12}O_6$, but have different configurational formulae.
- All the monosaccharides act as **reducing sugars** as these reduce cupric sulphate of Fehling's solution and Benedict's solution to brick red precipitates of cuprous oxide.

sucrose is considered to be 100. It is common **cane** or **table sugar.**

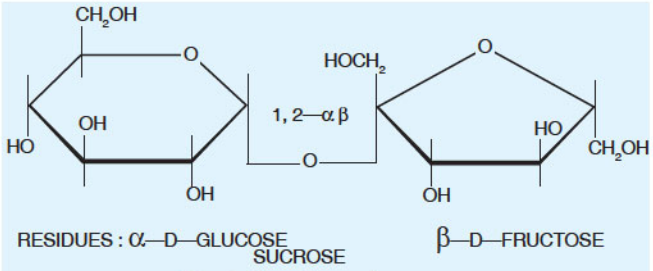


Fig. 3. Structure of sucrose.

(c) Lactose (Milk sugar) (Fig. 4). It is composed of β-D-glucose and α-D-galactose units interlinked by β(1→4) glycosidic bond. It is also called **milk sugar** and constitutes 5% of mammalian milk. Sweetening power is 16.

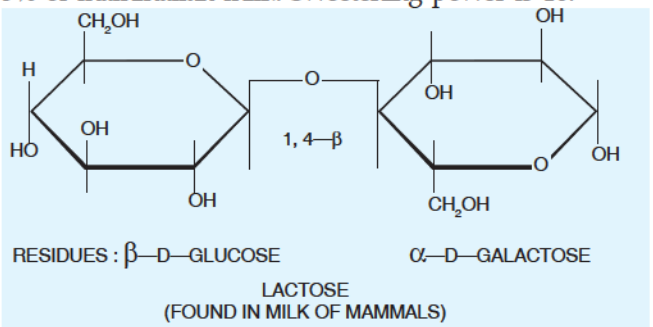


Fig. 4. Structure of lactose.

Trisaccharides. Raffinose is a common trisaccharide found in plants. Raffinose is found in sugarbeet, coffee etc. It is non-reducing sugar.

Functions. Some important functions of oligosaccharides are :

(a) Fuel. Disaccharides can act as fuel to provide energy.

(b) Storage food. Sucrose is the reserve storage product in sugarbeet and sugarcane.

(c) Recognition point. Oligosaccharides attached with cell membrane help in recognising the cells of their own kind.

(d) Sucrose is main **transport sugar** in the phloem of plants.

III. NUCLEOTIDES

Nucleotides are **building blocks of nucleic acids** (DNA and RNA). A nucleotide is formed of 3 components :

(i) Pentose sugar. It is a 5-C sugar and always occurs in furanose form. It is **D-ribose** in RNA and **2′-D-Deoxyribose** in DNA.

(ii) Nitrogen base. A nitrogen base is a N-containing heterocyclic basic ring compound. In two types of nucleic acids, there are 5 types of nitrogen bases, out of which only one base is present in a nucleotide.

Out of these nitrogen bases, DNA contains A, G, C and T, while RNA contains A, G, C and U. Adenine and Guanine are substituted purines while cytosine, thymine and uracil are substituted pyrimidines.

(iii) Phosphate group. It is derived from phosphoric acid and is present in both DNA and RNA.

Formation of Nucleotides. The nitrogen base is linked with the pentose sugar at C-1′ by a **glycosidic bond** formed by dehydration synthesis. This combination of a nitrogen base and a pentose sugar is called a **nucleoside.** There are four types of nucleosides in both DNA and RNA respectively called **deoxyribosides** (deoxyadenosine, deoxyguanosine, deoxythymidine and deoxycytidine) and **ribosides** (Adenosine, Guanosine, Cytidine and Uridine). A **nucleotide** is the phosphate ester of a nucleoside in which a phosphate molecule is joined at C-5′ of pentose sugar by an anhydro bond. So **a nucleotide** (Fig. 4) **is the phosphate ester of a nucleoside.** In DNA, there are four types of nucleotides called **deoxyribotides** (d-AMP, d-GMP, d-CMP and d-TMP) and similarly in RNA, there are four types of nucleotides called **ribotides** (AMP, GMP, CMP and UMP) (Table 4)

Table 2. Types of Nitrogen bases (Fig. 5)

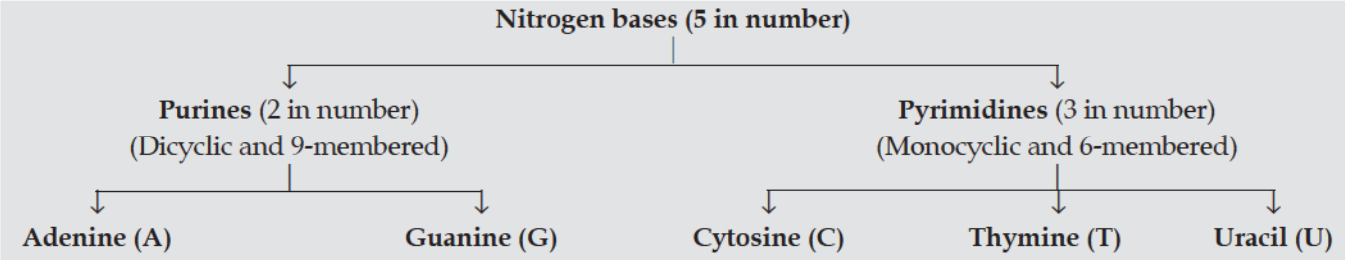


Table 3. Differences between Purine and Pyrimidine.

Characters	Purine	Pyrimidine
1. Number	A purine is nine-membered.	A pyrimidine is six-membered.
2. Rings	A purine is double ringed and larger sized nitrogen containing biomolecule.	A pyrimidine is a single ringed structure and smaller sized nitrogen containing biomolecule.
3. Nitrogen atoms	Purines bear four nitrogen atoms at 1', 3', 7' and 9' positions.	Pyrimidines bear two nitrogen atoms at 1' and 3' positions.
4. Examples	Adenine (A) and Guanine (G).	Cytosine (C), Thymine (T) and Uracil (U).

Table 4. Nucleosides and nucleotides of DNA and RNA.

Nitrogen Base	RNA		DNA	
	Ribosides	Ribotides	Deoxyribosides	Deoxyribotides
Adenine (A)	Adenosine	Adenylic acid	Deoxyadenosine	Deoxyadenylic acid
Guanine (G)	Guanosine	Guanylic acid	Deoxyguanosine	Deoxyguanylic acid
Cytosine (C)	Cytidine	Cytidylic acid	Deoxycytidine	Deoxycytidylic acid
Thymine (T)	—	—	Thymidine	Thymidylic acid
Uracil (U)	Uridine	Uridylic acid	—	—

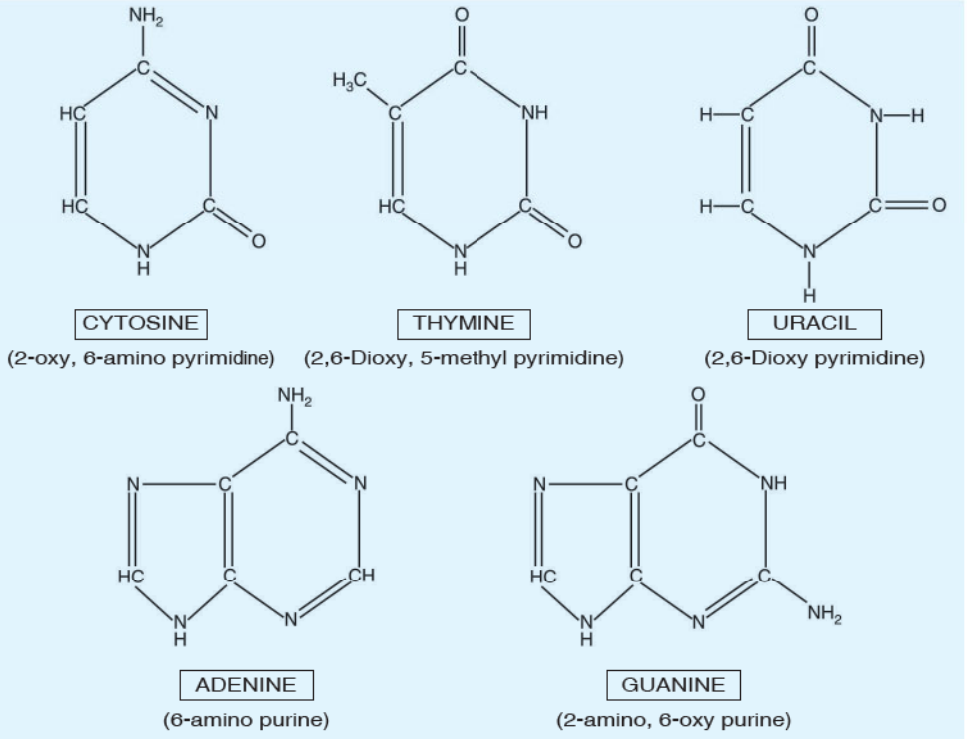


Fig. 5. Types of Nitrogen bases.

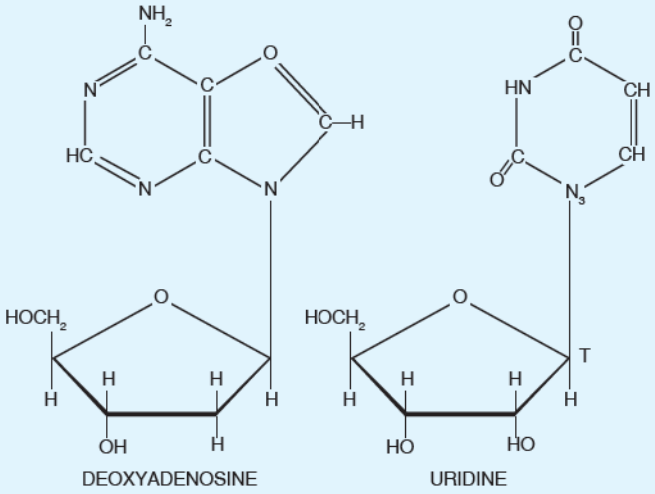


Fig. 6. Two types of nucleosides in DNA and RNA.

Table 5. Differences between Nucleoside and Nucleotide.

Character	Nucleoside	Nucleotide
1. Constitution	It is formed by union of a nitrogenous base with pentose sugar.	It is formed by union of nitrogenous base, pentose sugar and phosphate.
2. Nature	It is slightly basic in nature.	It is acidic in nature.

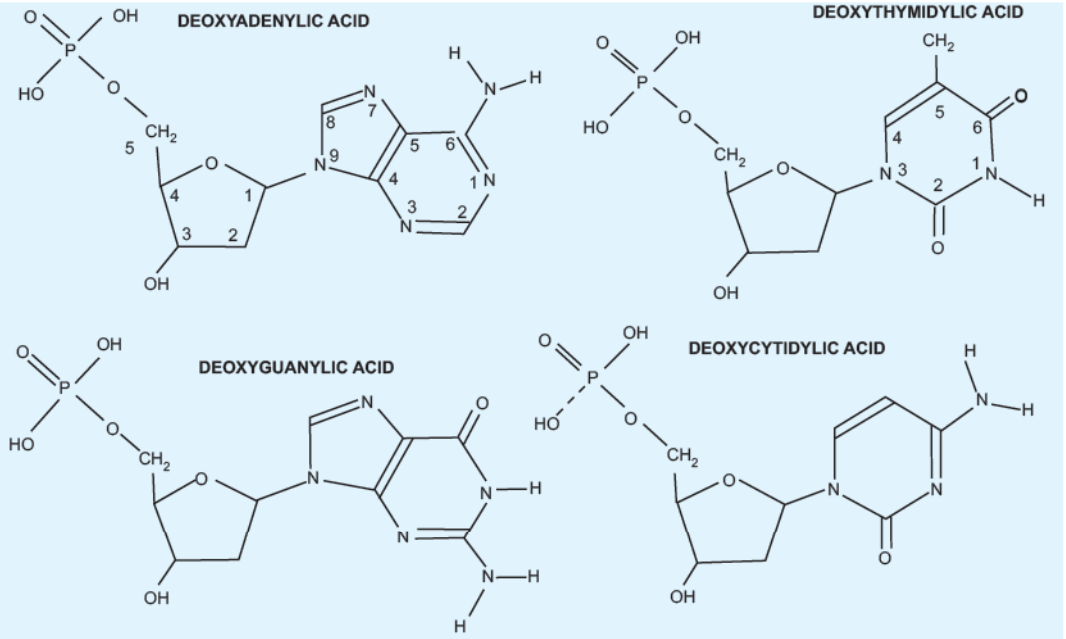


Fig. 7. Four major nucleotides in DNA.

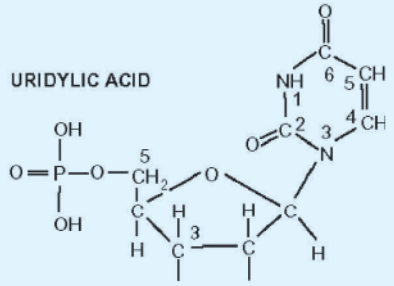


Fig. 8. A nucleotide of RNA (uridylic acid).

Functions of Nucleotides :

1. Nucleotides act as **building blocks** of both types of nucleic acids (RNA and DNA).

2. Higher nucleotides act as **energy carriers** e.g. ATP (commonly called **energy currency**) and GTP.

3. Some nucleotides act as structural components of **coenzymes** like FMN, FAD and NAD which act as H-acceptors along with the dehydrogenases.

4. Cyclic AMP acts as second messenger for the quick-acting hormones like epinephrine.

5. Cyclic GMP regulates Ca^{2+} or calmodulin-mediated chemical reactions.

6. Nucleotides react with pantothenic acid to form **coenzyme-A.**

7. UDP and **ADP** take part in the biosynthesis of polysaccharides.

8. CDP and **CTP** are involved in the biosynthesis of phospholipids.

IV. FATTY ACIDS AND GLYCEROL

Fatty acids and glycerol are the **building blocks of lipids (fats).**

Fatty acids. Fatty acids are organic molecules made up of long hydrocarbon chain which contain a terminal (—COOH) carboxyl group. The hydrocarbon chain (—R group) may be a methyl (—CH_3) or ethyl (—C_2H_5) or higher number of —CH_2 groups (1 to 19 carbons). **Acetic acid** CH_3COOH is a simple fatty acid and **stearic acid** $CH_3(CH_2)_{16}COOH$ is more complex while **Arachidonic acid** is a 20C unsaturated fatty acid.

Physical nature of fat is determined by the chain length of fatty acids and whether they are saturated or unsaturated. Fatty acids are called **saturated** if they do not bear double bonds between the carbon atoms of the molecular chain *e.g.* **palmitic acid** (16C) and **stearic acid** (18C) (Fig. 10). On the other hand, **unsaturated** fatty acids have one or more double bonds e.g. **oleic acid** (18C), **linoleic acid** and **linolenic acid** with 1, 2, and 3 double bonds respectively (Fig. 9).

The terminal carboxyl group is polar and is water soluble while the hydrocarbon group is non-polar and insoluble. Fatty acids become less and less water soluble as the length of their hydrocarbon increases. Unsaturated fatty acids have lower melting points than saturated fatty acids. Oils have lower melting point so remain as liquid fats even in winters e.g., **gingelly oil.**

The categories of Fatty acids

On the basis of **nature of bonds,** fatty acids are divided into **two categories : saturated fatty acis** and **unsaturated fatty acids** (Table 6) :

Table 6. Differences between Saturated and Unsaturated fatty acids.

Character	Saturated fatty acid	Unsaturated fatty acid
1. Occurrence	More common in **animal tissues.**	More common in **plant tissues.**
2. Nature of chain	Straight chain compounds.	Bending in their structure.
3. Nature of bonds	Single bonds only.	One or more double bonds.
4. Physical nature	Solid at room temperature.	Liquid at room temperature, so called **oils.**
5. General formula	$C_n H_{2n} O_2$.	$C_n H_{2n-2x} O_2$.
6. Melting point	High.	Low.
7. Examples	**Palmitic acid :** $CH_3—(CH_2)_{14}—COOH$ **Stearic acid :** $CH_3—(CH_2)_{16}—COOH$ (Fig. 10).	**Oleic acid** (18C) (Fig. 9) : $CH_3—(CH_2)_7—CH = CH—(CH_2)_7—COOH$

On the basis of **their synthesis,** fatty acids are divided into **two categories : essential fatty acids** and **non-essential fatty acids** (Table 7) :

Table 7. Differences between Essential and Non-essential fatty acids.

Character	Essential fatty acid	Non-essential fatty acid
1. Synthesis	Cannot be synthesized in the body tissues and must be present in the diet.	Can be synthesized in the body tissues so may or may not be present in the diet.
2. Occurrence	Present in a number of vegetable oils e.g. safflower oil.	Mainly present in animal fats e.g. butter.
3. Examples	**Linoleic acid, Linolenic acid** and **Arachidonic acid.**	**Palmitic acid, Stearic acid, Oleic acid, etc.**

Glycerol. Fats and oils are esters derived from glycerol (a trihydroxy propane) and fatty acids. Glycerol has chemical formula $C_3H_5(OH)_3$. Normally, three fatty acids can join a glycerol molecule. So the glycerol serves as a **binder or carrier** for fatty acids.

Formation of fats. The chemical bond between glycerol and fatty acids is called **ester** bond. Three hydroxyl groups of glycerol molecule (Fig. 11) can unite with the carboxyl group of three fatty acids to form **fat** or **lipid** molecule. Most lipids are esters of glycerol. That is why these are called as **glycerides.** As a result 3 molecules of water get eliminated. Neutral animal fats formed from 16 carbon palmitic acid and 18 carbon stearic acid are called as **tripalmitin** and **tristearin** respectively. These are pure fats. An example of mixed fat is **palmito-oleio-stearin.** In this case fat bears a molecule each of palmitic, oleic and stearic acid. Depending upon the number of fatty acid molecules found esterified with glycerol, the fats are called **monoglycerides** (one fatty acid esterified with glycerol), **diglycerides** and **triglycerides** (also called **neutral fats**).

(Types of Lipids have been discussed ahead).

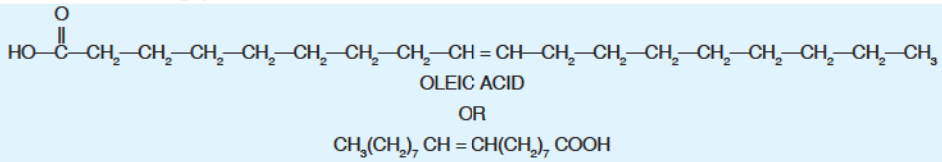


Fig. 9. Unsaturated fatty acids.

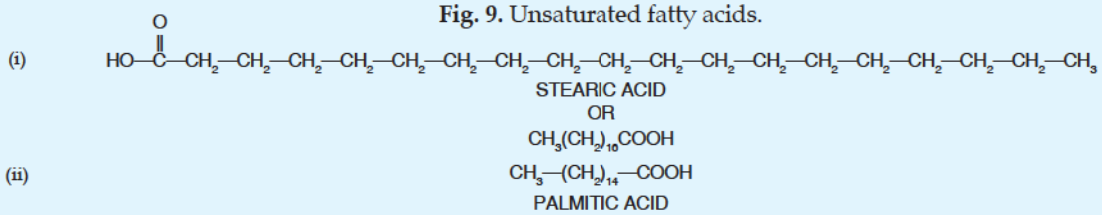


Fig. 10. Saturated fatty acids.

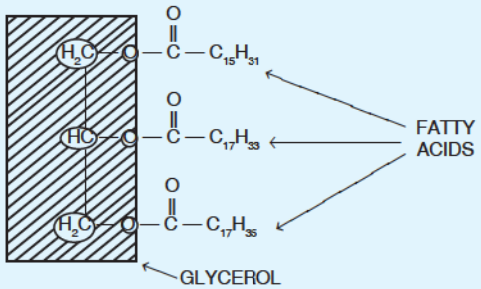
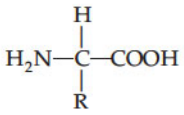


Fig. 11. Formation of a Triglyceride fat molecule.

V. AMINO ACIDS

Proteins constitute the structural framework of all components. Proteins are linear polymers of long chains made up of amino acids. Thus, proteins have high molecular weight. Amino acids can be called as **building blocks of proteins**. All the amino acids have the general structure given below:



NH_2 = Amino group, COOH = Carboxyl group, R = Alkyl group.

Composition. Amino acids (Fig. 12) are small molecules made up of carbon, hydrogen, oxygen, nitrogen and little sulphur. Amino acids are organic acids having a carboxyl group (COOH) with an amino group (NH_2) on the alpha carbon atom (next to COOH). The carboxyl group is responsible for giving acidic properties, whereas amino group attributes basic ones. Amino acids are monocarboxylic or dicarboxylic bearing one or two amino acids. From the structural formula, it is obvious that four valencies of a carbon bear an amino group, a carboxyl group, a hydrogen atom and a variable side chain (R). So amino acids are **substituted methanes.** This side chain may be polar or non-polar.

Types. When amino group is free, it is said to be basic and when carboxyl group is free,it is said to be acidic. Examples of **basic amino acids** are lysine and arginine as they contain two amino groups and one carboxyl group. Glutamic acid (glutamate) and aspartic acid (aspartate) bear one amino group and two carboxyl groups, hence called as **acidic amino acids**. Some examples of **neutral amino acids** are alanine, lysine, valine and phenylalanine as they contain only one carboxyl group and one amino group. Physical and chemical properties of amino acids depend upon three functional groups: amino group, carboxyl group and R side chain.

Zwitter ionic nature

A peculiar property of amino acids is their ionisable nature of their —NH_2 and —COOH groups to —NH_3^+ and —COO^- by transfer of H–atom from —COOH to —NH_2 group. This doubly charged ionic form of amino acids is called **zwitter ion.** It depends upon the pH of the solution. So an amino acid can act as either an acid (proton donor) or a base (proton acceptor).

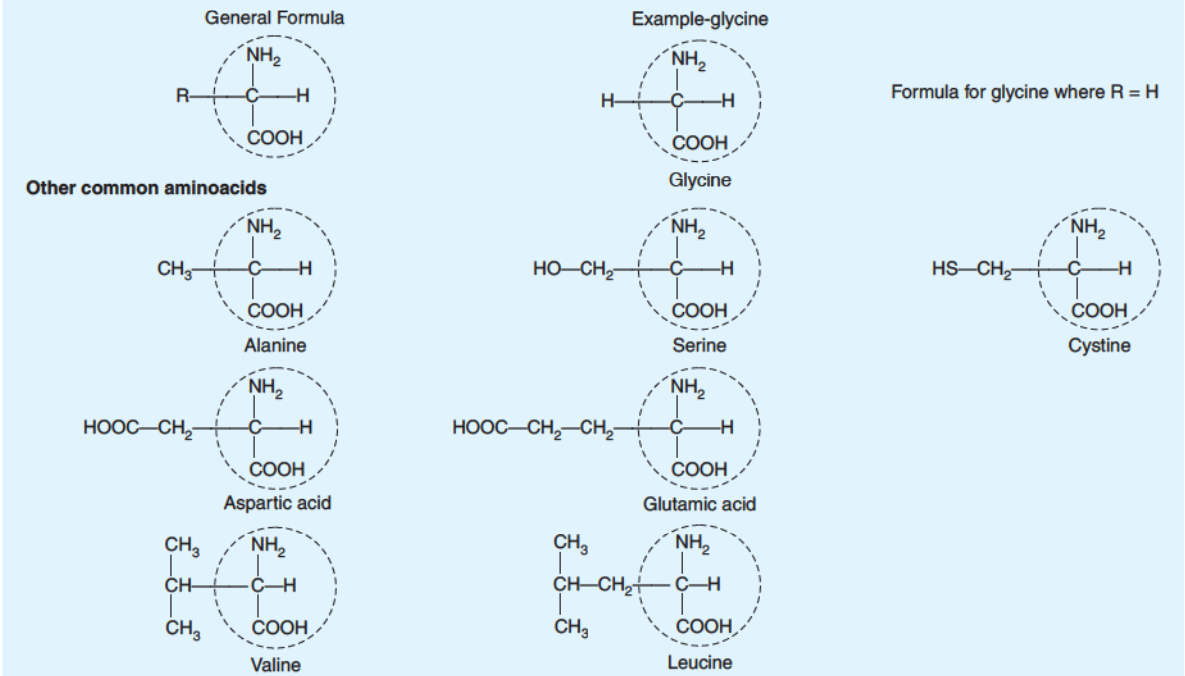


Fig. 12. Structure of some very common amino acids.

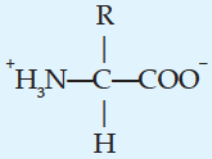


Fig. 13. Zwitter ionic form of Amino acid.

Two types of Amino acids on the basis of their synthesis (Table 8)

Table 8. Differences between Essential and Non-essential amino acids.

Characteristics	Essential amino acids	Non-essential amino acids
1. Synthesis	Cannot be synthesized in the body tissues.	Can be synthesized in the body tissues.
2. In diet	Must be present	May or may not be present.
3. Number	8 in number	12 in number.
4. Examples	Leucine, Isoleucine, Lysine, Methionine, Threonine, Valine, Phenylalanine and Tryptophan.	Alanine, Asparagine, Aspartic acid, Cysteine, Glutamic acid, Glutamine, Proline, Serine, Tyrosine, Arginine, Glycine and Histidine.

FUNCTIONS OF AMINO ACIDS

1. Protein macromolecules are polymers formed due to condensation of amino acids.
2. Tyrosine forms hormone, thyroxine and adrenaline.
3. Tyrosine also takes part in the formation of skin pigment melanin.
4. Glycine converts itself into haeme.
5. Tryptophan takes part in the formation of vitamin nicotinamide.
6. Tryptophan is the precursor of IAA (indole 3 acetic acid) a plant growth hormone.
7. With the removal of amino groups many amino acids form glucose.
8. Active amines as histamines are formed due to removal of carboxyl groups in the form of CO_2.
9. Non-protein amino acids are components of antibiotics.
10. Ornithine and citrulline play a role in urea cycle and liver cells.

REMEMBER

- Fatty acid molecules are **amphipathic molecules** because their hydrocarbon chain is hydrophobic while their —COOH group is hydrophilic.
- Unsaturated fatty acids may be **monoenoic** (e.g. oleic acid with one double bond), **dienoic** (e.g. linoleic acid), **trienoic** (e.g. linolenic acid) or **tetraenoic** (e.g. arachidonic acid).
- **Prostglandins** are derived from arachidonic acid and were isolated from the prostate glandular tissue by **Samuelsson and Bergstrom.** These regulate the synthesis of C—AMP which mediates the action of quick acting hormones. These also help in vasodilation, contraction of uterine muscles, etc.
- **Bloor :** Scientist who classified the lipids into three categories.
- **Polyunsaturated oils** are recommended in diet as these lower the blood cholesterol level e.g. sunflower oils, safflower oils, etc.
- **Paraffin wax** is obtained from petroleum.
- **Bile acids** (e.g. glycocholic acid and taurocholic acid) and **steroid hormones** (e.g. β-estradiol of ovary, testosterone of testis, and corticoids of adrenal cortex) are derived from cholesterol.

PRIMARY AND SECONDARY METABOLITES (TABLE 9)

Metabolites are those biomolecules which are either utilized in metabolic functions or are synthesized by the cellular machinery. These are of **two types :**

1. **Primary metabolites,** and
2. **Secondary metabolites.**

Table 9. Differences between Primary metabolites and Secondary metabolites.

Character	Primary metabolites	Secondary metabolites
1. Occurrence	Found in all the cell types.	Only in plant, fungal and microbial cells.
2. Nature of functions	Play known functions in normal physiological processes.	No identifiable functions performed, though some are useful to human welfare while some have ecological importance.
3. Examples	**Amino acids, carbohydrates, nucleotides, fats,** etc.	**Alkaloids, rubber, pigments, essential oils, antibiotics** etc.

Table 10. Some secondary metabolites.

Pigments	Carotenoides, Anthocyanins, etc.
Alkaloids	Morphine, Codeine, etc.
Terpenoides	Monoterpenes, Diterpenes etc.
Essential oils	Lemon grass oil, etc.
Toxins	Abrin, Ricin.
Lectins	Concanavalin A.
Drugs	Vinblastin, curcumin, etc.
Polymeric substances	Rubber, gums, cellulose.

ADD TO YOUR KNOWLEDGE

- **Cellular pool :** Collection of various types of molecoles in a cell.
- Glucose is commonly called **grape sugar,** while fructose is commonly called **fruit sugar.**
- Glucose is a **dextro-rotatory sugar** (rotates the polarized light towards right) while fructose is a **leavo rotatory sugar.**
- Trisaccharides (e.g. **Raffinose, Rabinose**); Tetrasaccharides (e.g. **Stachyose, Scorodose**); Pentasaccharides (e.g. **Verbacose**).
- **Trehlose** is a disaccharide found in some fungi and haemolymph of some insects.
- **Magic 20 :** Twenty types of biologically important amino acids.
- Souring of milk occurs when bacteria convert lactose into lactic acid.
- **Aromatic amino acids** are : tyrosine, phenylalanine and tryptophan.
- **Alcoholic amino acids** are serine and threonine.
- **Heterocyclic amino acids** are proline, histidine, tryptophan and hydroxyproline.
- **Sulphur-containing amino acids** e.g. cysteine and methionine.
- **GABA** (Gamma-aminobutyric acid) is a non-protein amino acid. It acts as an inhibitory neurotransmitter in brain.
- Lipids are insoluble in water but are not strictly macromolecules.
- **Heterocyclic amino acids are :** Proline, hydroxyproline, histidine, and tryptophan.
- **Glycine** is the simplest amino acid.
- **Water** is the most abundant chemical compound of cellular pool. It forms **70 to 90%** of it.

PRACTICE PROBLEMS – BIOMICROMOLECULES

1. Define cellular pool.
2. List the protoplasmic elements.
3. Name two fractions obtained during chemical analysis of living tissue.
4. What are building blocks of proteins?
5. Name two basic amino acids.
6. What do you mean by Zwitter ion?
7. List one difference between essential and non-essential amino acids.
8. Give the general formula of monosugars.
9. Give one difference between furanose and pyranose ring.
10. What are building blocks of nucleic acids?
11. List three components of a nucleotide.
12. Name four types of nucleotides of RNA.
13. List a difference between nucleoside and nucleotide.
14. What are triglycerides.
15. Give one difference between primary and secondary metabolites.

ANSWERS TO PRACTICE PROBLEMS

1. Collection of different types of biomolecules of a cell.
2. Six in number : C, H, O, N, P and S.
3. Acid-soluble pool called **filtrate** and acid-insoluble **retentate.**
4. Amino acids.
5. Arginine and lysine.
6. When a chemical compound has both negative and positive charges e.g. amino acids.
7. Essential amino acids cannot be synthesized inside the cells e.g. Lysine, Leucine. Non-essential amino acids can be synthesized inside the cells e.g. Glycine, Alanine.
8. $C_n(H_2O)_n$ or $(CH_2O)_n$.
9. Furanose ring is 5-membered ring e.g. of all pentoses and fructose. Pyranose ring is 6-membered ring e.g. Glucose, Galactose, Mannose, etc.
10. Nucleotides.
11. Nitrogen base, pentose sugar and phosphate group.
12. r-AMP; r-GMP; r-CMP and r-UMP
13. **Nucleoside** is the combination of nitrogen base and pentose sugar. **Nucleotide** is the combination of nitrogen base, pentose sugar and phosphate.
14. In a triglyceride, three similar or different fatty acids are attached to three hydroxyl groups of glycerol by ester bonds.
15. **Primary metabolites** are found in all the cells while **secondary metabolites** are found in plants, fungal and microbial cells.

BIOMACROMOLECULES

These are large sized biomolecules of high molecular weights (ranging ten thousand daltons and above **except lipids** whose molecular weight does not exceed 800 daltons) and are formed by the linking of a number of microbiomolecules, commonly called **monomers,** by specific bonds so are also called **polymers** except lipids. These are present in acid-insoluble fraction and are of four types of organic compounds :

1. **Proteins** (10–15%) : Average 12%
2. **Polysaccharides** (complex sugars) (3%)
3. **Lipids** (2%)
4. **Nucleic acids** (5–7%)

Why lipids categorised in Macrobiomolecules?

Lipids are not strictly macromolecules becasue these are not polymeric compounds and also have low molecular weight of about 800 daltons only. But still these are categorised into macrobiomolecules because, these are found in acid insoluble fraction. It is so as these are mainly present in the biomembranes which form water insoluble vesicle when broken into pieces on grinding a tissue. These are water insoluble organic biomolecules.

A. PROTEINS

Term "**protein**" was coined by **J. Berzelius** (1838) from Greek word '*proteious*' because these are of **prime importance** in biochemical reactions. These form the **most important** and **most abundant** intracellular organic biomolecules and form about **10–15% (Average 12%)** of cellular pool.

General structure. Proteins are polymers of amino acids which are interlinked by the **peptide bonds** formed by **dehydration synthesis**. So these are macro biomolecules of high molecular weight (ranging from 4500 daltons in ACTH to 40 million daltons of TMV proteinous capsid). These are **most diverse biomolecules** as any one of 20 amino acids may occur at any point in modified or unmodified form so are generally **heteropolymer compounds.**

Formation of Peptide bond (Fig. 14) between the amino acids—

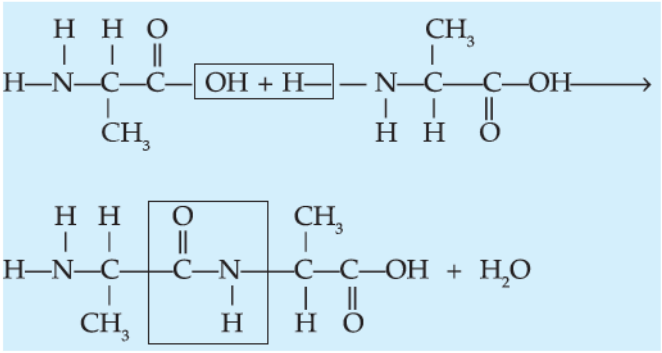


Fig. 14. Formation of peptide bond.

Hofmeister and Emile Fischer proposed that the amino acids of a protein are interlinked by **peptide bonds** formed by loss of water molecule **(dehydration synthesis)** between —OH group of —COOH group of one amino acid and —H atom of α–NH_2 group of adjacent amino acid. So the proteins are called **polypeptides.** Each poly peptide chain has two specific ends : **N-terminus** (end with free —NH_2 group of first amino acid at left end) and **C—terminus** (end with free carboxyl group of last amino acid at right end).

Four structural models of proteins (Table 11) – Fig. 15

Table 11. Four structural models of proteins.

Structural model	Properties	Examples
1. Primary structure	● Linear arrangement of amino acids. ● Amino acids held by covalent bonds like peptide and disulphide bonds.	Insulin hormone (Fig. 16). Ribonuclease enzyme.
2. Secondary structure	● Spatial (conformational) arrangement of amino acids. ● Amino acids held by peptide bonds and **intra-molecular H-bonds or intermolecular H-bonds.**	α-Helix model of keratin (Fig. 17). β-pleated model of fibroin protein of silk fibre.
3. Tertiary structure	● Polypeptide chain folded to form a **three dimensional globular structure.** ● Stabilized by ionic bonds, H-bonds, hydrophobic bonds and disulphide bonds (Fig. 20).	All the enzymatic proteins and myoglobin of muscles (Fig. 21).
4. Quaternary structure	● Relative folding of two or more similar or dissimilar polypeptides upon one another. ● Stabilized by H-bonds, hydrophobic bonds and electrostatic or salt linkages.	Haemoglobin of blood-formed of two α-type subunits and two β-type subunits (Fig. 22). Lactic acid dehydrogenase enzyme.

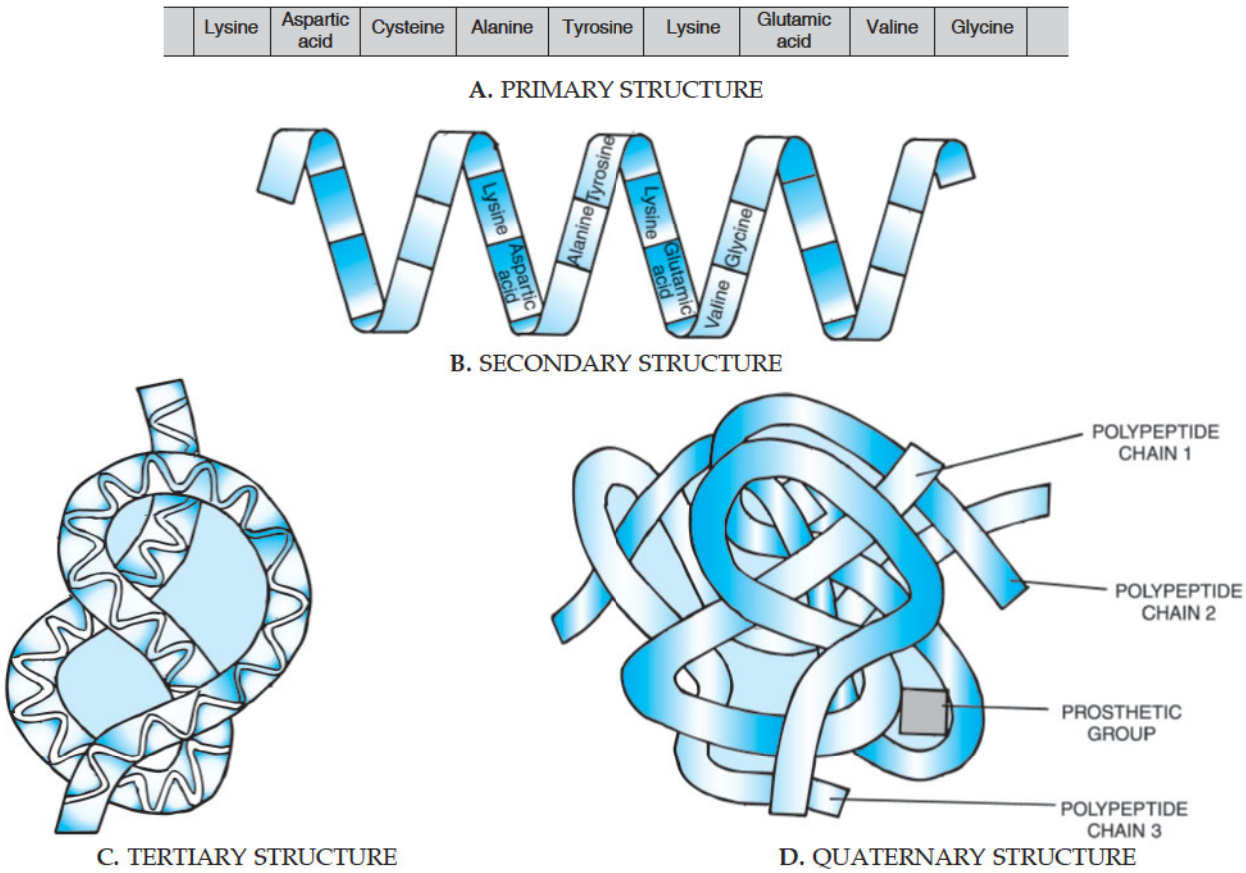


Fig. 15. Different structural models of proteins.

Primary structure of insulin was first determined by **Frederick Sanger** (1954). It is formed of two polypeptide chains : **A– and B– chain,** interlinked covalently by two disulphide bonds (Fig. 16). A chain is formed of 21 amino acid residues, while B-chain is formed of 30 amino acid residues. A third disulphide bond also occurs in the A–chain. **Primary structure of ribonuclease** was determined by **Hirs, Moore and Stein (1960).** It consists of a single polypeptide chain of 124 amino acid residues and has four disulphide bonds between 8 cysteine residues.

Two structural models of secondary structure :

Linus Pauling and Corey (1951) demonstrated that there are two structural models of secondary structure : **α-Helix model** and **β-pleated model** (Table 12) :

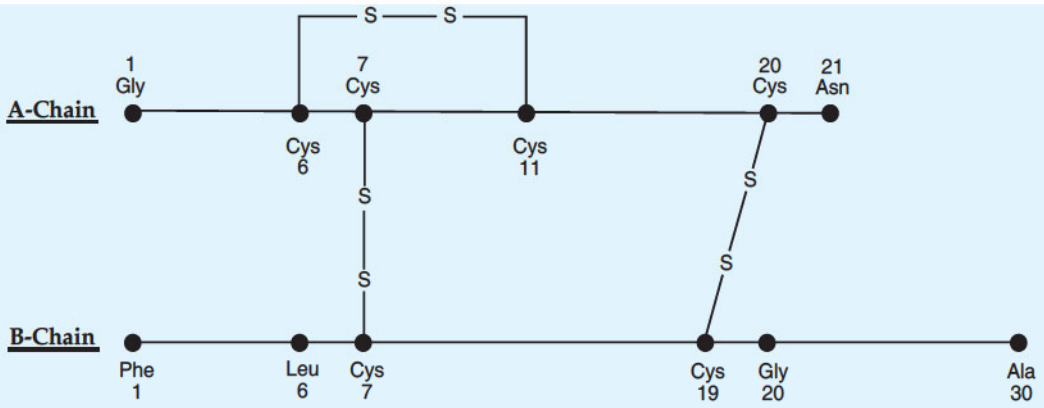


Fig. 16. Primary structure of human insulin (Diagrammatic).

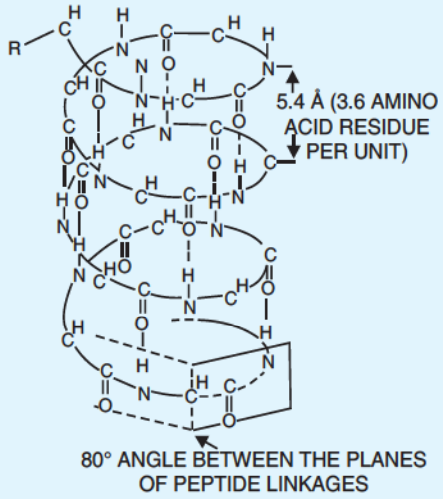


Fig. 17. Helicoidal state of α-helix.

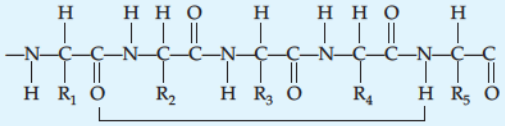


Fig. 18. α-Helical nature of proteins (every third imide group linked along the chain by hydrogen bond).

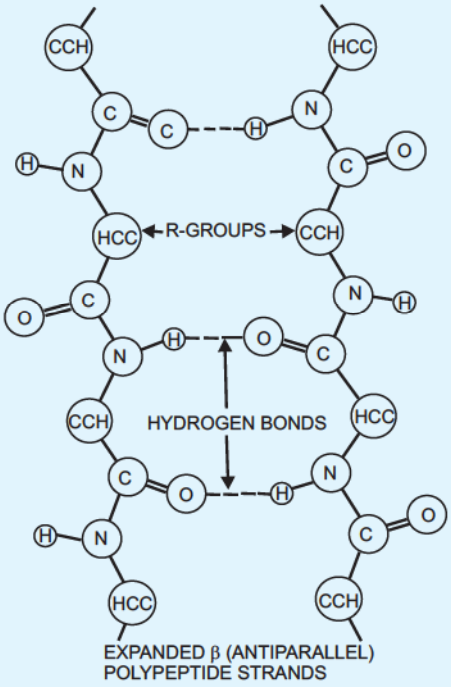


Fig. 19. H-bonds in β-pleated sheet.

Table 12. Differences between α-Helix and β-pleated sheet model.

Character	α-helix Model (Fig. 17)	β-pleated sheet Model (Fig. 19)
1. Nature of polypeptide chain	**Spirally coiled** like revolving staircase and side groups are outward directed.	Polypeptide chains are arranged **parallel or anti-parallel** in zig-zag manner.
2. Nature of H-bonds	**Intramolecular** H-bonds between *n*th and *n*-4th amino acids (Fig. 18).	**Intermolecular H-bonds** between amino acids of adjacent chains.
3. Disulphide bonds	Present between cysteine residues of adjoining chains.	No cysteine residues, so no disulphide bonds.
4. Inter-molecular distance	1.5 Å.	3.5 Å.
5. Examples	**α-keratins** of epidermal exoskeletal structures.	**Fibroin protein** of silk fibres.

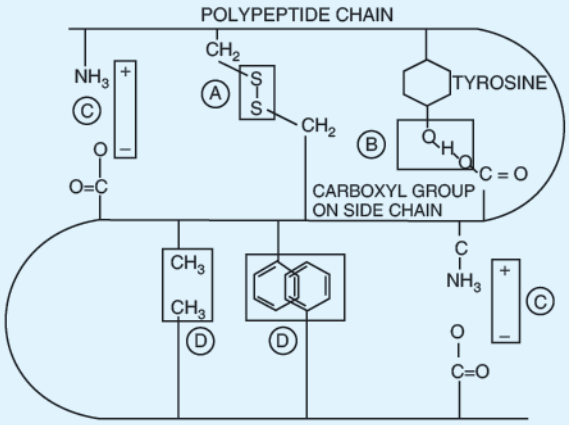


Fig. 20. Diagram of types of bonds in a tertiary protein.
A. Disulphide bond. **B.** Hydrogen bonds.
C. Electrostatic interaction. **D.** Hydrophobic interactions of non-polar side chains.

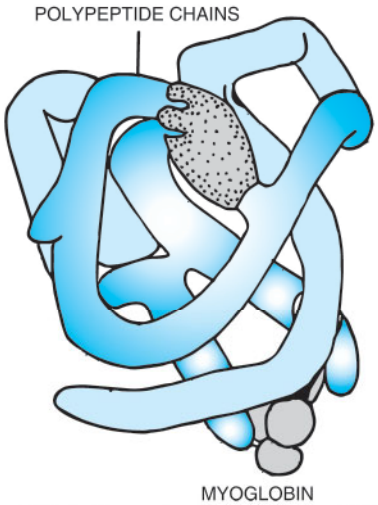


Fig. 21. Tertiary structure of myoglobin.

Quartenary structure of Haemoglobin (Fig. 22)

Haemoglobin is a **tetrameric protein** formed of 4 polypeptide chains and 4 haeme prosthetic groups, each having iron in ferrous state. There are 2 alpha and 2 beta chains so is represented as $\alpha_1\beta_1 - \alpha_2\beta_2$. Each α-chain is formed of 141 amino acid residues while each β-chain is formed of 146 amino acid residues. These four chains are folded upon one another to form a **tetrahedral quartenary structure.**

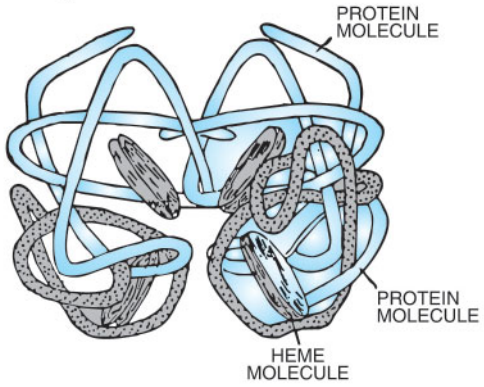


Fig. 22. Quartenary structure of haemoglobin molecule.

TYPES OF PROTEINS

(a) On the basis of shape : On the basis of their shape, the proteins are divided into **two categories** (Table 13) : **Globular proteins** and **Fibrous proteins.**

(b) On the basis of chemical composition : On this basis, the proteins are divided into **three categories :**

(i) Simple proteins (Holoproteins). These proteins are formed of only amino acids so on hydrolysis, these yield only amino acids or their derivatives *e.g.* **albumins, globulins, prolamine, protamins, histones, scleroproteins, collagen** of white fibres, **α-heratin** of epidermal derivatives, certain enzymes like **ribonuclease** and **chymotrypsinogen,** etc. These are further subdivided on the basis of their solubility.

(ii) Conjugated proteins (Heteroproteins). In these proteins, a protein is associated with a non-proteinous compound, called **prosthetic group,** which is essential for the biological functioning of proteins. On the basis of prosthetic groups, the conjugated proteins are classified into following sub-categories (Table 14).

(iii) Derived proteins. These are products of denaturation or partial digestion of proteins (Table 15).

Table 13. Protein types on the basis of shape.

Character	Globular proteins	Fibrous proteins
1. Structure	In these, the polypeptide chains are compactly folded to form compact spherical or globular shaped proteins.	In these, the polypeptide chains are extended along one axis and are spirally wound to form fibres.
2. Nature of bonds	4 types of bonds : H-bonds, ionic bonds, disulphide bonds and hydrophobic bonds which maintain a **tertiary structure.**	H-bonds between the amino acid residues of same chain or adjoining chains, so usually have a high degree of **secondary structure.**
3. Solubility	These are generally soluble in water and also soluble in dilute acids, alkalies and salts.	These are insoluble in water but soluble in concentrated acids or alkalies.
4. Contractility	These are non-contractile.	These are contractile.
5. Examples	**Egg albumin, serum albumin, globulins, haemoglobin, all enzymes, proteinous hormones** like insulin, **venom** of snake and scorpion, **glutelins** of wheat, etc.	**α-Keratins** of hair, nails, claws, horns, hoofs, scales and feathers, **fibroin** of silk fibres, **fibrin** of blood clot, **collagen** of tendon, **elastin** of ligament, **myosin** and **actin** of muscles, etc.

Table 14. Types of Conjugated Proteins.

Protein type	Characteristics	Examples
1. Nucleoproteins	Basic proteins (protamines or histones) + nucleic acid.	**Deoxyribonucleoproteins** in chromosomes of nuclei and **ribonucleoproteins** in ribosomes.
2. Lipoproteins	Combination of proteins with lipids (fatty acids, cholesterol and phospholipids).	**Egg yolk, serum and cell membranes.**
3. Glycoproteins or Proteoglycans	Combination of proteins with mucopoly-saccharides.	**Mucin** (Saliva), **Ovomucoid** (egg white), **Osseomucoid** (bone), **blood antigens,** pituitary hormones like **FSH, LH.**
4. Phosphoproteins	Proteins associated with phosphoric acid residue.	**Casein** (milk), **ovovitellin** (egg yolk).
5. Chromoproteins	Proteins associated with certain porphyrin ring pigment.	**Haemoglobin, haemocyanin, myoglobin, cytochromes, rhodopsin, iodopsin, flavoproteins.**
6. Metalloproteins	Proteins associated with certain metal ions (*e.g.* Fe, Co, Mg, Zn, Cu, etc.) as cofactor.	**Ferritin** (Fe), **Carbonic anhydrase** (Zn), **Catalase** (Fe), **Plastocyanin** (Cu), **Nitrogenase** (Mo), **Hexokinase** (Mg).

Table 15. Types of Derived Proteins.

Protein type	Characteristics	Examples
1. Proteans	Formed in the early stage of protein digestion by dilute acids, enzymes or alkalies.	**Fibrin** from fibrinogen. **Myosan** from myosin. **Proteoses** and **peptones.**
2. Metaproteins	Formed in the later stage of protein digestion by slightly stronger acids and alkalies.	**Acid or alkali metaproteins.**
3. Coagulated proteins	Denatured proteins formed by the action of heat, UV-rays, X-rays, etc.	**Cooked proteins, coagulated albumins.**

Functions of proteins (Table 16)

Table 16. Biological importance of Proteins.

Protein type	Biological importance	Examples
1. Structural proteins	Growth and repair of body tissues so called **building blocks of the body.**	**α-keratin** (hair nails etc.), **ossein** (bone), **tubulin** (forms microtubules of cilia, flagella, centriole etc.) **chondrin** (cartilage), **collagen** (forms intercelluar ground tissue), **fibroin** (silk fibres), etc.
2. Enzymatic proteins	Act as **biocatalysts** so regulate body functions.	**Pepsin** and **trypsin** (help in digestion).
3. Hormonal proteins	Regulate the metabolism.	**Insulin** (regulates sugar level in blood).
4. Transport (carrier) proteins	Transportation of materials.	• **Haemoglobin** of RBCs (transports O_2 and CO_2). • **GLUT-4** (Transports glucose into the cells). • **Permeases** of cell membrane help in active transport. • **P-protein** of phloem transports nurtients.
5. Contractile proteins	Help in movements and locomotion.	**Myosin** and **actin** of muscles.
6. Protective proteins	• Act as **antibodies** and provide immunity • Blood clotting at the injury.	**γ-Globulins** of lymphocytes. **Prothrombin** and **fibrinogen** of blood.
7. Visual proteins	Help in vision so found in retinal cells.	**Rhodopsin** of rods and **iodopsin** of cones.
8. Toxic proteins	Help in defence as well as offence.	Snake venom, ricin of castor, etc.
9. Storage proteins	As reserve food.	**Casein** (milk), **ovlabumin** (egg white), **gliadin** (wheat), **zein** (maize), etc.
10. Receptor proteins	Act as **hormone receptors** on target cells.	**β**-adrenaline (epinephrine receptor).

Collagen is the most abundant protein in animal world, while **Rubisco enzyme** is the most abundant protein in whole of the biosphere.

B. POLYSACCHARIDES

Composition. Polysaccharides, also called **glycans,** are the polymers of more than 10 monosaccharides interlinked by **glycosidic bonds** formed by dehydration synthesis. Different polysaccharides differ in the nature and number of their monosaccharides, and degree of branching. Most frequently used monosaccharide in their formation is D-Glucose. General formula of polysaccharides is :

$= (C_6H_{10}O_5)_n$ where n is the number of monosugars. **Two categories of polysaccharides.** On the basis of **nature of monosaccharides,** polysaccharides are divided into **two categories : Homopolysaccharides** and **Heteropolysaccharides.**

1. Homopolysaccharides. These are formed of only one type of monosaccharides e.g. **cellulose, starch, glycogen, inulin, agar, xylan, araban,** etc.

(i) Cellulose (Fig. 23). It is an insoluble and rigid structural polysaccharide found in the cell wall of most of algae, all higher plants, certain protists and fungi. It forms about 25–50% of wood and about 90% of cotton fibres. It is a linear and unbranched homo-polysaccharide of about 6,000 to 10,000 -D-Glucose molecules interlinked by **β-(1→4) glycosidic bonds.** Its molecular weight ranges between 0.5 to 2.5 million.

As cellulose does not contain complex helices so cannot hold iodine and gives **no colour with iodine.**

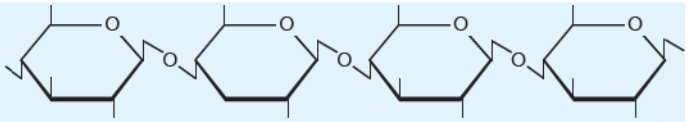


Fig. 23. Structure of cellulose.

(ii) Starch (Fig. 24). It is a **storage homopolysaccharide** of plants and is found as species specific shaped and sized grains in the potato tubers, corn seeds, cereals like rice, wheat etc., and fruits like banana, mango, etc. Chemically, the starch is formed of two glucose polymers : **α-Amylose** (an unbranched but spiral chain of about 200 to 2000 α-Glucose molecules interlinked by α (1→4) glycosidic bonds) and **amylopectin** (a branched glucan of about 2,000 to 20,000 α-Glucose molecules so forming helical secondary structure). Glucose molecules are interlinked by α(1→4) glycosidic bonds except the bond between Glucose of main chain and first glucose of branch which is α(1→6) glucosidic bond. Starch can hold iodine molecules in the helices so **gives blue colour with iodine.**

(iii) Glycogen. It is also a **storage homopolysaccharide** like the starch but is found in the muscles and liver cells of animals so is also called **animal starch.** Like the amylopectin of starch, it is also a **branched homopolysaccharide** formed of about 30,000 α-D-Glucose molecules. Its molecular weight is about 4 million and it gives **red coloured with iodine.**

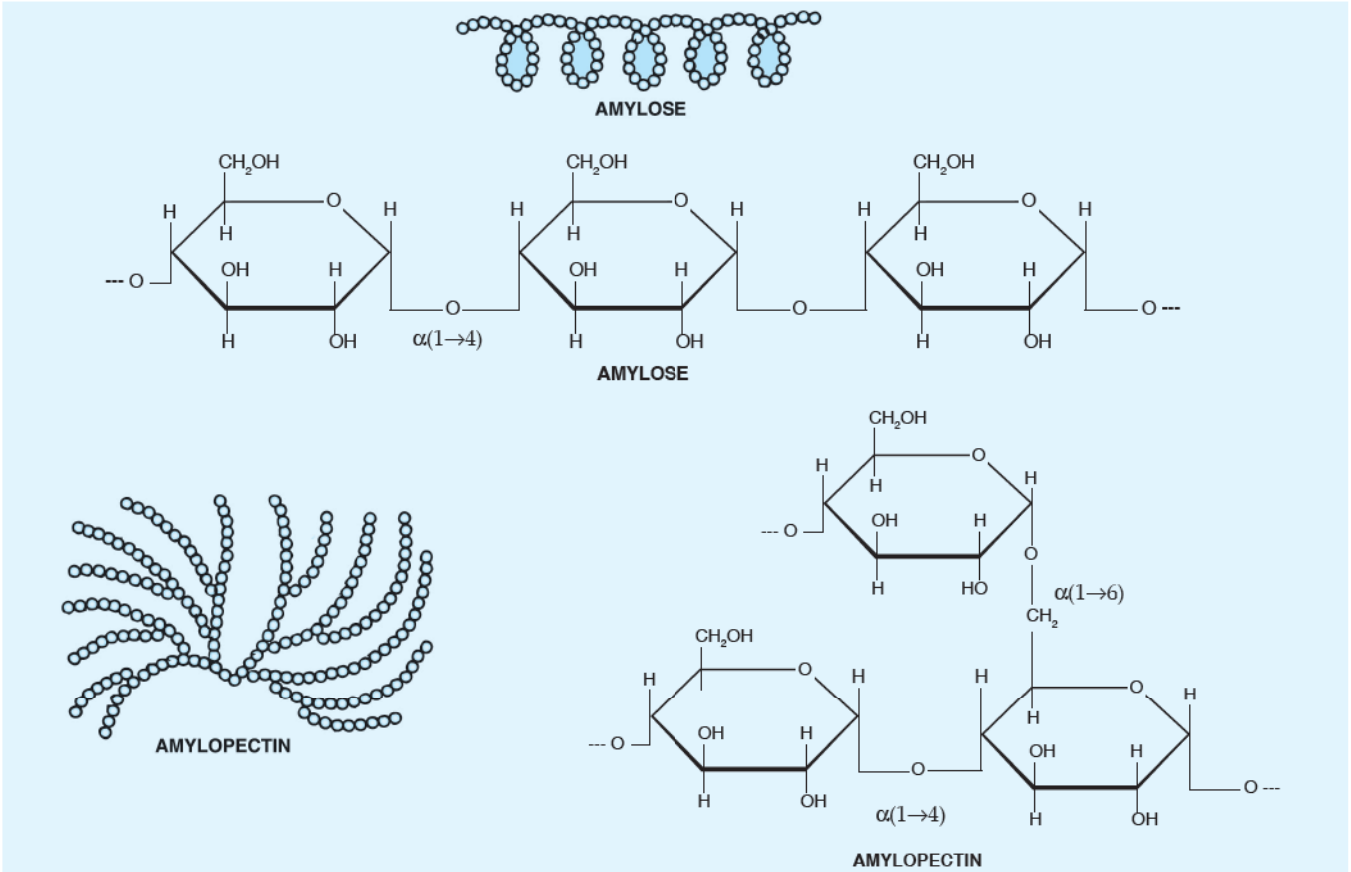


Fig. 24. Molecular structure of starch.

A polysaccharide chain has two specific ends : right **reducing end** and left **non-reducing end.**

2. Heteropolysaccharides. These are formed of two or more types of monosaccharides or their derivatives like amino sugars like glucosamine, N-acetyl galactosamine; or sugar acids like glucuronic acid, etc. So these are heteropolymers and are more complex than the homopolysaccharides e.g.

(i) Chitin (Fig. 25). It is a neutral hetero-polysaccharide found in the exoskeleton of crustaceans (e.g. crabs, prawns, lobsters, etc.), in the cell wall of most of fungi so is also called **fungal cellulose.** It is a polymer of **N-acetyl glucosamine** units interlinked by **β(1→4) glycosidic bonds.**

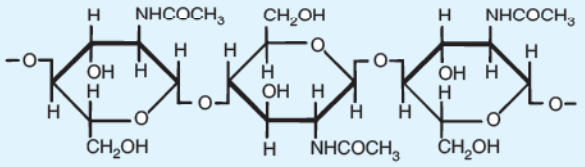


Fig. 25. A part of chitin polysaccharide.

(ii) Hyaluronic acid. It is a linear acidic hetero-polysaccharide found in various lubricating fluids of body e.g. **synovial fluid** of limb joints, around the ovum, etc.

(iii) Peptidoglycans (Murein). It is found in the cell wall of **bacteria** and **cyanobacteria.** It is formed of a polysaccharide chain linked with tetrapeptide molecules. It prevents the lysis and osmotic inflow of the cell wall.

Functions of polysaccharides

1. As reserve food. Starch is the storage food of most of the plants while **glycogen** is the principal reserve food of liver and muscle fibres of animals. **Inulin** is storage food of dahlias, onion, garlic, etc.

2. Structural polysaccharides.

(i) Cellulose, hemi-cellulose and pectins are structural polysaccharides of cell wall of plants.

(ii) Chitin is structural polysaccharide of cell wall of fungi and exoskeletal plates of arthropods.

(iii) Chondroitin sulphate is a structural heteropolymer of cartilages.

(iv) Peptidoglycans form the cell wall of bacteria and cyanobacteria.

3. Anticoagulation. It acts as anticoagulant and prevents blood clotting inside the blood vessels.

4. Cellulose forms the **roughage** of food and stimulates peristalsis and secretion of digestive juices from the digestive glands.

5. Agar is used as **tissue culture,** laxative and food.

6. Cellulose is also the main component of cotton fibres and paper formed from paper pulp.

7. Hyaluronic acid lubricates the synovial joints between the bones and allows frictionless movements.

8. Hormones like FSH and LH are **glycoproteinous** in nature and help in reproductive activities.

9. Blood antigens are glycoproteins and give **immunological properties** to the blood.

C. NUCLEIC ACIDS

General structure. Nucleic acids are macromolecules of utmost importance. These are polymeric compounds of nucleotides so are called **polynucleotides.** Each nucleotide is formed of **three components :**

1. Heterocyclic nitrogen base
2. Pentose sugar } (Already explained)
3. Phosphate group

Formation of nucleotides } (Also already explained)
Types of nucleotides

Formation of a polynucleotide chain (Fig. 26)

A polynucleotide chain is formed by interlinking of large number of nucleotides by **5′–3′ phosphodiester bonds.** These bond link the 5′-carbon of a pentose of a nucleotide with 3′-carbon of a pentose of adjoining nucleotide. The bond between sugar and phosphate molecule is called an **ester end** while the linking of phosphate group to two sugar molecules is called **phosphodiester bond** (Fig. 26). So the backbone of a nucleic acid chain is formed of alternatively arranged phosphate and pentose sugar molecules while the nitrogen bases 'stick out' inward from the pentose sugars of the backbone.

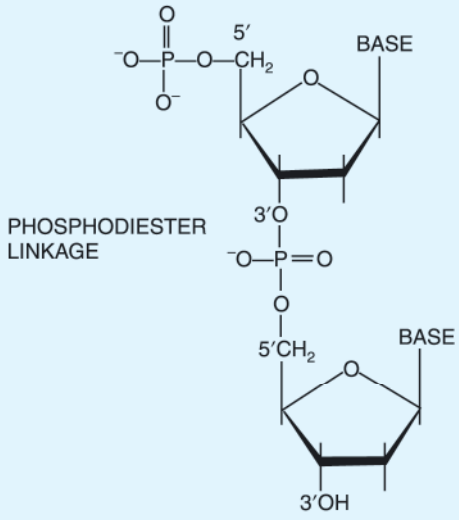


Fig. 26. Interlinking of nucleotides.

Table 17. Differences between Reducing and Non-reducing sugars.

Character	Reducing sugars	Non-reducing sugars
1. Nature	Reduce cupric ions of Fehling's reagent and Benedict's reagent to cuprous ions to produce brick-red precipitates.	Donot form brick-red precipitates with Fehling's reagent and Benedict's reagents.
2. Structural peculiarity	Have free carbonyl group (either aldehydic or ketonic group).	Donot have free carbonyl group.
3. Examples	All monosaccharides, Maltose, Lactose, etc.	Sucrose and all polysaccharides.

Each nucleic acid chain has **two specific ends :**

● **5′ end** is with free —OH group at 5′-carbon of terminal nucleotide.

● **3′ end** is with free —OH group at 3′-carbon of terminal nucleotide.

Types of Nucleic acids. Beherens (1938) classified the nucleic acids into **two classes :**

1. Deoxyribose nucleic acid (DNA).

2. Ribose nucleic acid (RNA).

1. Deoxyribose nucleic acid (DNA)

(i) Occurrence. It is mainly found in the nucleus of all the living cells except some viruses e.g. TMV. It was later also reported in a number of cell organelles like mitochondria, plastids, etc.

(ii) Watson and Crick's model of B-DNA (Fig. 27)

On the basis of previous findings; **James Watson** (America) and **F.C.H. Crick** (England) proposed the most accepted model of DNA in 1953. It explains all the properties of DNA including equivalence rule, semi-conservative replication and its role in heredity. Main postulates of DNA model are :

(a) It is formed of two right handed polynucleotide chains which form a **double helix**.

(b) Each polynucleotide chain is formed of large number of nucleotides which are interlinked by **5′-3′ phosphodiester bonds.** In DNA, four types of **deoxyribotides** are : d-AMP, d-GMP, d-CMP and d-TMP.

(c) Each polynucleotide chain has **specific polarity** i.e. with two specific ends (3′ end and 5′ end).

(d) The backbone of each chain is formed of alternatively arranged phosphate and pentose sugar molecules, while the nitrogen bases are directed inside the helix perpendicular to backbone because these are hydrophobic in nature. This arrangement gives **ladder-like appearance.** Pentose sugar is always **2′-deoxyribose.**

(e) There is **specific base pairing (Fig. 27)** between the nitrogen bases of two chains. A purine always pairs with a pyrimidine an *vice verse*. Even purine-pyrimidine pairing is also specific e.g.

Adenine always pairing with Thymine by 2 H-bonds, and Cytosine always pairing with Guanine by 3 H-bonds.

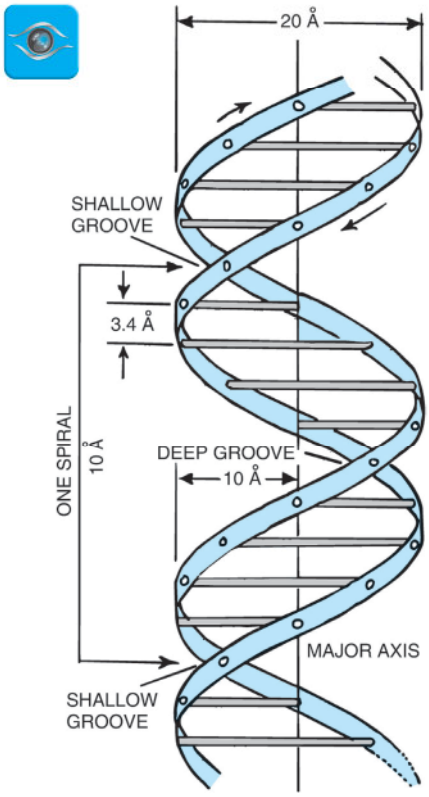


Fig. 27. Watson and Crick model of B-DNA.

(f) DNA helix completes a turn by every **34Å (3.4 nm)** and since the internucleotide distance is 3.4Å (0.34 nm) so each DNA helix has **10 nucleotide pairs per spiral of DNA molecule.**

(g) DNA molecule is a **regular molecule** with a uniform diameter of about **20Å.**

(h) The nitrogen base sequence of two polynucleotide chains is **complimentary to each other.**

(i) Two DNA strands are **antiparallel** to each other i.e. the 5′-3′ phosphodiester linkages are in opposite direction.

(j) Each base pair is rotated about 36° around the axis of the helix in relation to next base pair.

(k) DNA has a **shallow groove** of about 12Å across and a **major groove** of about 22Å across.

Table 18. Differences between Prokaryotic DNA and Eukaryotic DNA.

Character	Prokaryotic or Circular DNA	Eukaryotic or Linear DNA
1. Quantity	Small, less than 0.1 pg.	High, more than 1 pg.
2. Association	It is naked DNA, no histones.	Organelle DNA is naked but nuclear DNA is associated with histones.
3. Shape	Circular.	Nuclear DNA—linear. Organelle DNA—Circular or linear.
4. Location	It is freely present in cytoplasm. Absent in organelle.	Present only inside the nucleus and semi-autonomous organelles.
5. Introns	Absent.	It bears introns or superfluous regions.
6. Plasmids	May be present.	Usually absent.

Table 19. Differences between DNA and RNA.

Character	DNA	RNA
1. Occurrence	Mainly found in the chromosomes in the nucleus; also reported in some cell organelles like mitochondria, plastids etc.	Mainly found in the cytoplasm; also reported in the chromosomes (about 5%).
2. Nature of helix	Generally double helix.	Generally single helix.
3. Average number of nucleotides	4.3 million Comparatively high mol. wt. (varies from 2 to 6 million).	12,000 Comparatively low mol. wt. (varies from 25,000 to 2 million).
4. Types	2 types—Linear, Circular.	2 types — Genetic, Non-genetic— t-RNA, m-RNA, t-RNA.
5. Types of nitrogen bases	A, G, C and T Uncommon bases are less.	A, G, C and U. More uncommon bases.
6. Pentose sugar	2-Deoxyribose ($C_5H_{10}O_4$)	Ribose ($C_5H_{10}O_5$)
7. Replication	Always replicates.	Replicates only in some viruses e.g. **Paramyxoviruses.**
8. Transcription	Transcribes RNAs	RNA of Retroviruses has power of reverse transcription.
9. Translation	Controls translation indirectly.	Has direct control on translation.
10. Quantity	Species specific.	Varies in different cells.
11. Equivalence rule	Applicable A : T = 1 : 1; C : G = 1 : 1 Due to complimentary base pairing.	Not applicable. No base pairing.
12. Diameter	Regular molecule with a diameter of 20Å	Not a regular molecule.
13. Nature of 5′ end	May be with a purine or a pyrimidine.	Always with a purine (with A or G).
14. Functions	Controls growth, repair, metabolism, heredity, differentiation and evolution.	Mainly involved in protein synthesis.

(iii) Functions of DNA

(a) DNA acts as **genetic material** in most of organisms so controls growth, development, differentiation, reproduction, etc.

(b) DNA controls the synthesis of **structural proteins** which help in growth and repair of body tissues.

(c) DNA controls the synthesis of **enzymatic proteins** which regulate metabolism.

(d) Gene mutations in DNA produce **variations** in the population which help in speciation and **evolution.**

So DNA forms the very basis of life, so is rightly called **blue print.**

2. Ribose nucleic acid (RNA)

(i) Occurrence. RNA is mainly present either as free form in the cytoplasm or in some cell organelles (like ribosomes, mitochondria and plastids) though also reported in the chromosomes (about 5%). In all plant viruses (e.g. TMV) and some bacteriophages, RNA acts as genetic material.

(ii) RNA structure. RNA differs from DNA in following characteristics (Table 19) :

(ii) Functions of RNAs

(a) Genetic RNA is involved in transmission of characters through generation. *e.g.*, RNA viruses like TMV, HIV, Reo virus, Paramyxovirus, etc.

(b) Non-genetic RNAs help is protein synthesis called **translation.** These are of three types.

THREE TYPES OF NON-GENETIC RNAs

A. MESSENGER RNA (mRNA)

Jacob and Monod (1961) gave the idea for the first time that the chemical messenger between DNA of nucleus and metabolic machinery of cytoplasm is mRNA. DNA acts as a template for the formation of mRNA.

The size of mRNA is related to the size of message it contains. Synthesis of mRNA begins at 5' end of DNA strand and terminates at 3' end. From pores in the nuclear membrane, mRNA comes out into cytoplasm and finally it attaches itself to a ribosome or polysome.

B. RIBOSOMAL RNA

The site of protein formation is ribosome. They are formed of proteins and ribosomal RNA (rRNA). **Ribosomal RNA (rRNA)** is also formed from DNA in the nucleolar organizing region of chromosome. In cytoplasm, rRNA and various proteins assemble together to form ribosomes.

C. TRANSFER RNA (t-RNA)

Transfer RNA molecules are much smaller bearing 70-80 nucleotides so is **smallest sized** RNA type. It is water soluble. It is also single stranded but due to number of complementary sequences after pairing it is shaped like clover leaf **(Holley, 1965)**. Each tRNA can pick up particular amino acid so called **adopter RNA**. At the end of tRNA, 3 unpaired nucleotides are present. This group of 3 nucleotides matches up with the complementary 3 nucleotides of mRNA. The three nucleotides of mRNA are called as **codon**. And the complementary matching, 3 nucleotides of tRNA is called the **anticodon**. The specific amino acid is added to the stem of clover leaf of tRNA. Following four parts can be recognised on tRNA (Fig. 28) :

(a) DIHU (Dihydrouracil loop) or amino acid recognition site.

(b) Amino acid binding site with–CCA-OH sequence.

(c) Anticodon loop or codon recognition site.

(d) Ribosome recognition site or GTPCG loop.

D. LIPIDS

1. Introduction. Lipids are naturally occurring heterogeneous organic compounds which are insoluble in water but soluble in fat solvents, and on hydrolysis yield fatty acids.

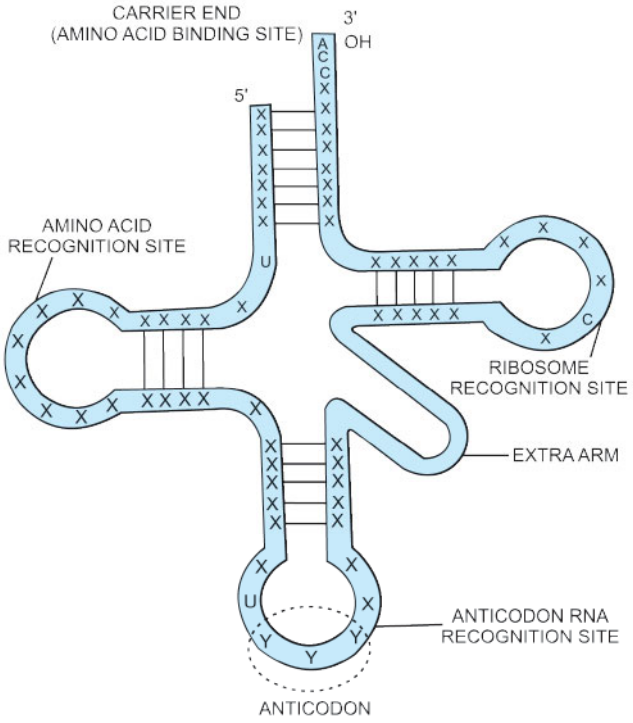


Fig. 28. Structure of tRNA.

2. Chemical composition. Triglycerides are chemically formed of **C, H and O** as in the carbohydrates but the number of oxygen atoms is less than carbon atoms. Phospholipids have nitrogen and phosphorus also.

3. Three categories of lipids. Bloor (1943) classified the lipids in **three categories** on the basis of **their chemistry :**

(i) Simple lipids or true lipids.

(ii) Conjugated or compound lipids.

(iii) Derived lipids.

(i) Simple lipids. These are esters of fatty acids with

Table 20. Types of Nucleic Acids.

Name	Type of molecule	Location	Function
DNA (Deoxyribonucleic acid)	Macromolecule in shape of double helix with many thousands of subunits.	Mainly in nucleus, also in mitochondria and chloroplasts.	Acts as store of coded instructions for synthesis of all proteins required by the cell.
mRNA (Messenger ribonucleic acid)	Single-stranded polymer, with hundreds of subunits.	In nucleus and cytoplasm especially ribosomes.	Made on the DNA template. It carries coded instructions for synthesis of one or more proteins from nucleus to ribosomes.
rRNA (ribosomal ribonucleic acid)	Molecule very closely bound to protein fraction.	Only in ribosomes.	Forms part of ribosome structure. Helps in locating mRNA correctly on ribosome surface.
tRNA (Transfer ribonucleic acid)	Single-stranded polymer of less than one hundred subunits.	In the cytoplasm.	Many kinds of tRNA act as amino acid carriers. Take specific amino acid from cytoplasm to mRNA template on ribosome.

various alcohols. These are divided into **two categories** on the basis of nature of alcohol :

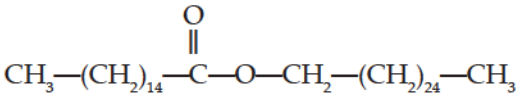
(a) Neutral fats and **(b) Waxes.**

(a) Neutral fats or glycerides. These are esters of fatty acids with glycerol alcohol, so a neutral fat is formed of two components : **Glycerol** and **Fatty acids.**

(Neutral fats have been explained earlier)

(b) Waxes. In these simple lipids, one molecule of higher fatty acid is esterified with a higher monohydric aliphatic alcohol other than glycerol e.g.

- **Plant waxes** form a water proof coating on the leaves to reduce rate of transpiration.
- **Bee wax** is secreted by abdominal glands of worker bees to make hive. It is palmitic acid (16 C) ester of mericyl alcohol (26 C).

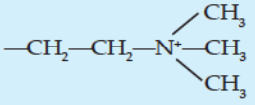
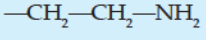
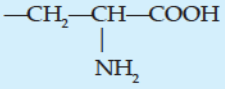


Hexacosyl palmitate

Fig. 29. Bee wax.

(ii) Phospholipids (Fig. 30). These are **phosphorus—containing conjugated lipids**. In a phospholipid, two fatty acids are linked to α-and β-OH groups of glycerol molecule by ester bonds while second α-OH group of glycerol is esterified with phosphoric acid which in turn is linked to a nitrogen base. A phospholipid molecule is an **amphipathic molecule** as its two long chain fatty acids (tails) represent the **hydrophobic (non-polar) end,** while phosphate containing end (head) represents **hydrophilic or polar end.** On the basis of nature of nitrogen base, phospholipids are of following types : **(Table 21)** :

Table 21. Types of Phospholipids.

Type of phospholipid	Nitrogen base	Formula of nitrogen base
1. Phosphatidyl choline (Lecithin) (Fig. 36)	Choline	
2. Phosphatidyl ethanolamine (Cephalin) (Fig. 37)	Ethanolamine	
3. Phosphatidyl serine	Serine	

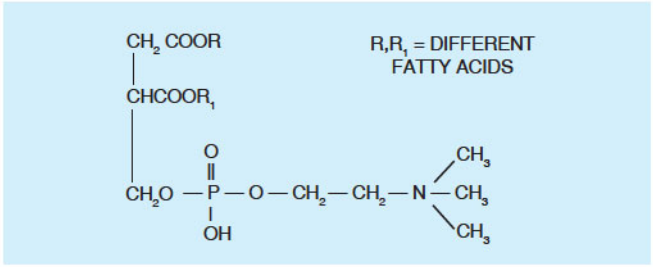


Fig. 30. Lecithin phospholipid.

Due to their amphipathic nature, the phospholipid molecules arrange themselves in a **bilayer arrangement (Fig. 31)** in aqueous medium. The hydrophillic (or polar heads) end of both the layers of phospholipid molecules face in opposite directions, while their hydrophobic (or non-polar tails) face towards each other and are held together by hydrophobic or vender Wall's forces of interactions. This bilayer arrangement of phospholipids form the **basic structural framework of the cellular biomembranes.**

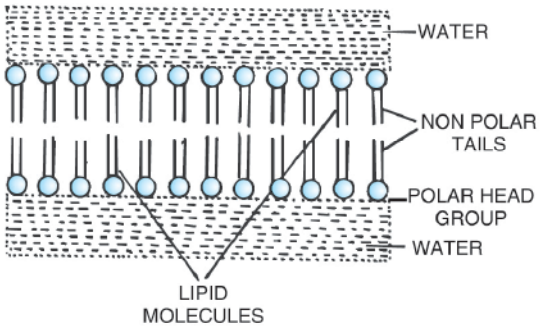


Fig. 31. Lipids bilayer in an aqueous medium.

(iii) Derived fats. These include lipid-like molecules like steroids, ketones, etc.

Steroids are solid, wax-like derived fats and always have a polycyclic ring, called **cyclopentano phenanthrene or sterane nucleus (17 C).** Most important steroids are **sterols** which are alcoholic compounds of the steroids. Some important steroids are :

(a) Cholesterol (Fig. 32A). It is **best known animal sterol** and is abundantly found in the nervous tissue. Its molecular formula is $C_{27}H_{45}OH$. Cholesterol acts as the component of **cell membrane** especially of RBCs. It also participates in the formation of **medullary sheath** over the nerve fibres. It also acts as a precursor of steroid hormones like cortisol, testosterone, estrogens, progesterone, etc.

(b) Ergosterol (Fig. 32B). It is found in the ergot fungus growing on the rye plants. It has a molecular formula of $C_{28}H_{43}OH$ and is the precursor of vitamin-D_2 in the presence of sunlight.

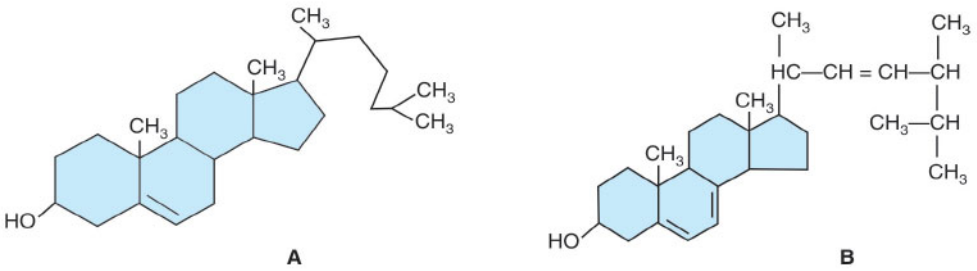


Fig. 32. Steroids : **A.** Cholesterol; **B.** Ergosterol.

Functions of Lipids :

1. Neutral fats (**Triglycerides**) act as **concentrated fuels** as their physiological fuel value of 1 gram is **9.0 Kcal** (about 2.25 times than that of glucose) but are not easily oxidisable.

2. Triglycerides are mainly stored **as reserve food** in the liver cells, beneath the skin, in the brown deposits and in the fat bodies of frogs and lizards. Fats are also stored in certain plants e.g. in the cotyledons of mustard, and in the endosperm of coconut and castor.

3. Fats present beneath the skin insulate the body, prevent the loss of body heat so help in **homeothermy** e.g. **blubber** under the skin of whales, seals, polar bear, etc.

4. Fats form **shock-absorbing cushions** around the kidneys, ovaries, etc. and in eyeball.

5. Fats help in **absorption of fat-soluble vitamins** like A, D, E and K.

6. Waxes form a **water-proof coating** on plant parts to reduce transpiration.

7. Waxes form **water-resistant layers** in insects, water-birds and furred mammals.

8. Wax papers are commonly used **for packing** perishable goods.

9. Lanolin fat is used in making ointment, cosmetic creams, etc.

10. Spermaceti oil acts as a lubricant for instruments.

11. Lecithins are the structural components of all the biomembranes, lipoproteins and egg yolk. It also acts as a component of acetylcholine (a neurotransmitter).

12. Sphingomyelins and **cephalins** form the medullary sheath of nerve fibres.

13. Lipoproteins are structural components of biomembranes.

14. Glycosphingolipids are responsible to tissue immunity and cellular recognition. These also provide blood group specificity and organ specificity.

15. Cholesterol acts as a precursor of bile salts, steroid hormones and vitamin-D_3. It is also the component of biomembranes of animals.

16. Ergosterol acts as a precursor of vitamin-D_2 in the presence of UV-radiations of sunlight.

17. Bile acids form **bile salts** which help in emulsification of fats.

18. Estrogens of ovary control development and functioning of secondary sex organs and secondary sexual characters of female.

19. Testosterone of testis controls development and functioning of secondary sex organs and secondary sexual characters of male.

20. Aldosterone of adrenal cortex regulates Na^+—K^+ balance in the body fluids.

21. Progesterone of ovary suspends ovulation and help in implantation, placentation and normal development of foetus.

22. Diosgenin steroid (obtained from *Dioscorea*–Yam plant) has antifertility propertics.

DID YOU KNOW?

- Best sources of animal proteins are : lean meat (22%), fish (16.5%) egg, milk etc.
- Animal proteins are called first class proteins as contain all the essential amino acids while plant proteins of pulses and beans are called second class proteins as do not contain all the essential amino acids.
- Animal proteins are rich in **lysine** while plant proteins are rich in **methionine.**
- **Soyabean** is the best source of plant proteins (43.2%).
- **Tertiary structure** of protein has a number of **active sites** so is absolutely necessary for the biological functioning of enzymatic proteins.
- **Monellin :** A protein obtained from African berry and is sweetest chemical (about 200 times than sucrose). It is non-caloric and nontoxic sweetener so is highly useful for diabetic patients.
- Polysaccharides are commonly called **glycans.** These are called **non-sugars** as are not sweeter in taste.

DID YOU KNOW?

- Each starch grain is formed of a common centre, called **hilum,** surrounded by centric or eccentric rings called **shells.**
- Starch, glycogen and cellulose are commonly called **glucans** as all of these are homopolymers of D-Glucose only. **Xylan** is polymer of xylose.
- In starch, **α-amylose** and **amylopectin** generally occur in the ratio of 1 : 4.
- **Inulin (Fructan)** is a polymer of fructose and is found in roots and tubers of dahlia, onion, garlic, etc. It is used to determine rate of ultrafiltration.
- **Agar (Galactan)** is a polymer of galactose and is found in cell wall of red algal sea weeds like *Gellidium* and *Gracillaria.*
- **Heparin** is a heteropolysaccharide secreted in blood plasma by liver cells.
- When ds DNA is treated at high temperature, two strands uncoil and separate. This is called **denaturation or melting** of DNA.
- When the denatured DNA is treated at low temperature, two separated strands again constitute ds DNA. This is called renaturation.
- **Chargaff's rule** state that in DNA A : T ratio; C : G ratio and purine (A + G) : pyrimidine (C + T) is always 1 : 1.
- Stain used to detect DNA is **Feulgen stain.**
- Genetic informations of DNA are in the form of base triplets, called **codes.** Each code being formed of 3 nucleotide pairs.
- **Z-DNA** has left handed double helical structure. Each helix has 12 nucleotide pairs. Helix rise (h) per base pair is 3.7 Å . It was reported by **Alexander** *et. al.* (1980).
- **Lanoline or wool fat** is secreted by cutaneous glands of lamb.
- **Spermaceti** is an oil extracted from head of sperm whole.
- Nucleic acids, polysaccharides and polypeptides collectively form the **true macromolecular fraction** of a living cell/tissue.
- Nucleic acid was first isolated by **F. Meischer** (1871) from the nuclei of pus cells while the term nucleic acid was given by **Altmann** (1889).
- In DNA, a GC pair is about 50% more stable than an AT pair.
- **Single stranded DNA** was reported in **ϕ × 174 virus** by **Sinsheimer** (1959).
- **H. Fraenkal Conrat :** Reported RNA as genetic material in TMV.
- **Double stranded RNA** is reported in wound tumour plant virus and Reo virus.
- **r-RNA** is the most abundant type of RNA (70–80% of RNA pool) and is found in the ribosomes.
- **m-RNA** is the carrier of genetic message of DNA in the form of base triplets called **codons.**
- **Genetic code :** Sequence of codons on m-RNA.
- **Repetitive DNA** (with sequence of nitrogen bases repeated a number of times) has been reported in satellite areas and heterochromatic areas of Y-chromosome.
- Other types of phospholipids are : **Plasmalogens** (one fatty acid is replaced by a long chain aliphatic aldehyde) and **Sphingomyelins** (Glycerol is replaced by an amino acid sphingosine).
- **Lecithin** is the most common type of phospholipid.

PRACTICE PROBLEMS – BIOMACROMOLECULES

16. Name the macrobiomolecules found in acid-insoluble fraction of cell.

17. Which type of bonds are found in the proteins and polysaccharides.

18. What does tertiary structure of a protein indicate?

19. Name two transport proteins.

20. List one difference between homopolysaccharide or heteropolysaccharide.

21. Why cellulose, starch and glycogen are commonly called glucans?

22. Why is chitin also called fungal cellulose?

23. Give the function of heparin.

24. Which types of bonds are found in nucleic acids?

25. What do you mean by antiparallel nature of two DNA chains?

26. Give one difference between B-DNA and Z-DNA.
27. What do you mean by amphipathic nature of phospholipids?
28. Name two derived lipids.

ANSWERS TO PRACTICE PROBLEMS

16. Proteins, polysaccharides, nucleic acids and fats.
17. Peptide bonds in protein and glycosidic bonds in polysaccharides.
18. Three-dimensional globular arrangement of a polypeptide chain.
19. Haemoglobin of RBCs and GLUT-4.
20. Homopolysaccharide is formed of one type of monosaccharides e.g. cellulose, starch and glycogen; while heteropolysaccharide is formed of two or more types of monosugars or their derivatives e.g. chitin, heparin etc.
21. All these are polymers of α-D-Glucose molecules.
22. Because chitin forms the cell wall of most of members of fungi.
23. Heparin acts as anticoagulant and prevents blood clotting inside the vessels.
24. Phosphodiester bonds.
25. 5′-3′ phosphodiester bonds direction is opposite in two chains of DNA.
26. B-DNA has 10 base pairs in a helix while Z-DNA has 12 base pairs in a helix.
27. It has both hydrophilic and hydrophobic end.
28. Cholesterol and ergosterol.

DYNAMIC NATURE OF BODY CONSTITUENTS—CONCEPT OF METABOLISM

A living system is characterised by its **steady state and homeostasis.** A steady state is a state of maximum efficiency due to following reasons :

1. Rate of input of matter and energy is equal to that of their output.

2. Concentration of different components of a system remains constant.

3. Rate of formation of each metabolite is exactly equal to its utilization.

Homeostasis is also an important property of life and is characterized by a dynamic constant internal environment of our body fluids. Due to this physiological equilibrium inside body, the metabolic functions proceed without interruption despite changes in the external environment. Homeostasis is a maintained by a number of self-regulating mechanisms which help in regulation of the level of various metabolites like sugar, minerals, water etc. at or near the required limits. The concentrations of various metabolites is generally expressed as **mols/cell or mols/litre** and is specific for the metabolites e.g. the blood glucose level in a normal healthy person is **60–100mg/100ml** (or 4.5–5.0 mM) while that of hormones is in **nanograms/ml.**

This constancy of level of various biomolecules is achieved through the process of **transformation of biomolecules** which involves the change of one type of biomolecules into another type and *vice versa* e.g.

1. Non-sugars like amino acids can be changed in glucose (sugar) by the process of **gluconeogenesis** in the liver cells.

2. Excess of amino acids are transformed into urea by the process of **deamination and detoxification** in the liver cells.

3. Conversion of amino acids (e.g. Histidine) into amine compounds (e.g. Histamine) by the process of **decarboxylation.**

4. Digestion of polysaccharides (e.g. starch) and disaccharides (e.g. sucrose) into monosaccharides by the process of **hydrolysis.**

Turn over is the number of biomolecules produced per unit time, while the sum of all the chemical reactions going on inside a living system is called **metabolism.** These metabolic transformations are not one-stepped processes but are multi-stepped processes, each of which being formed of a specific series of linked reactions called **metabolic pathways** e.g. **Glycolysis** is a ten-stepped metabolic pathway by which glucose molecule is changed into two molecules of pyruvic acids.

Two categories of metabolic pathways. Metabolic pathways of a living system are divided into **two categories** (Table 26).

1. Anabolic pathways and **2. Catabolic pathways.**

These metabolic pathways donot occur in isolation but are interlinked and may be linear (e.g. Glycolysis) or circular (e.g. ornithine cycle involving formation of urea). These also criss-cross one another but go on without any metabolic mishap for healthy conditions.

Table 22. Differences between Anabolic and Catabolic pathways.

Character	Anabolic pathways	Catabolic pathways
1. Nature	These are **constructive** or building up processes.	These are **destructive** or break down processes.
2. Energy	These are **endergonic reactions** and consume energy.	These are **exergonic reactions** and release energy.
3. Example	(i) Protein synthesis (Aminoacids → Protein) (ii) Acetic acid → Cholesterol (iii) Photosynthesis ($6CO_2+6H_2O$ → Glucose + $6O_2$)	(i) Glycolysis (Glucose → 2 Pyruvic acids) (ii) Muscle contraction (Glucose → 2 Lactic acids)

It is because certain **self-regulatory mechanisms** are located inside the body due to which this metabolic traffic is very smooth inspite of various traffic junctions and go on like the automobile traffic in a city.

Role of enzymes in metabolism

Another peculiar feature of the metabolic pathways is that every step of them is regulated by a specific enzyme so these are **enzyme-regulated reactions.** These enzymes act as metabolic regulators and direct the metabolic pathways along the desired directions at regulated temperature and quickly. It is so because these enzymes act as **biocatalysts** (so increase the rate of biochemical reactions). Presence of enzymes is a basic necessity of metabolism because their absence may result :

1. A **biochemical chaos** as a compound synthesized by anabolism may be immediately degraded by catabolism.

2. End product may be formed in excess then required which would cause **wastage of energy and raw materials.**

Role of ATP (Adenosine Triphosphate) in metabolism

Catabolic pathways are always energy releasing e.g. in **cell respiration,** glucose is enzymatically catabolised by stepped breakdown into water and CO_2, and about **686 kcal.** of energy is released per mole of glucose. A part of released energy is stored as chemical energy in the high energy bonds (~) of ATP molecules formed by phosphorylation of ADP.

ATP is commonly called **energy-cheque** because when required, it is hydrolysed and chemical energy is released which is used in various endergonic (energy-dependent) metabolic functions. So ATP acts as a link between energy-releasing (e.g. cell respiration) and energy-dependent (e.g. biosynthesis, growth, repair, locomotion, etc.) processes. **Fritz Lipmann proposed ATP cycle.**

The chemical energy released during the hydrolysis of ATP is used in different ways e.g.

1. As **light energy** in bioluminescence in glow worms.

2. As **mechanical energy** in muscle contraction for movements of body parts and locomotion.

3. As **electrical energy** in nerve impulse conduction on nerve fibres.

4. As **heat energy** in homeothermy.

This shows that the **most important form of energy for a living system is chemical energy. Bioenergetics** is the branch of science dealing with energy kinetics in the living systems. Term bioenergetics was coined by **Phillipson.**

Metabolic flux and steady state. Steady state, as mentioned earlier, in a living system is a **non-equilibrium state.** Due to transformation of biomolecules, these biomolecules are in a state of metabolic flux due to which the metabolites tend to reach the equilibrium state. But due to utilization of end products in metabolic pathway, the living system again comes in non-equilibrium state and it tends to achieve steady state by metabolic flux in the presence of energy provided by ATP molecules. This shows that **the living state and metabolism are synonymous** and without metabolism, there cannot be a living state.

ENZYMES

Definition. Enzymes are water soluble, colloidal organic macrobiomolecules which are wholly or partially proteinous in nature, biological in origin, produced in microamounts and capable of catalyzing specific biochemical reactions under specific conditions of temperature and pH.

Discovery. Louis Pasteur (1860) was first to propose that fermentation is caused by specific chemicals of yeast cells. Though the presence of enzyme was first reported by **W. Kuhne** (1878) but it was **Edward Buchner** (1897) who first isolated the enzyme from the yeast cells. Buchner gave the term **"enzyme"** from two Greek words : *en* = in; *zyma* = yeast, so enzyme means **"inside the yeast".**

Properties of Enzymes

1. Enzymes are **polymeric** organic compounds with high molecular weight.

2. Enzymes are wholly (e.g. **Amylase, Trypsin** and **Pepsin**) or partially (e.g. **Hexokinase, ATPase, Catalase, Succinate DHase**) **proteinous** in chemical composition except **Ribozymes and RNAase-P** are two non-proteinous enzymes in which RNA acts as catalyst.

3. Enzymes are required in **microamounts** as are used again and again.

4. Enzymes are **biological** in origin as are always produced by living cells.

5. These always have **3-dimensional tertiary structure** maintained by H-bonds, ionic bond, disulphide bond and hydrophobic forces of attraction.

6. These act as **biocatalysts** and help in reaching the equilibrium constant faster by lowering the energy barrier and required activation energy.

7. Enzymes are **substrate specific** e.g. maltase, sucrase and lactase can hydrolyse maltose, sucrose and lactose respectively.

8. Enzymes are **temperature specific.** Each enzyme is most active at a specific temperature called **optimum temperature** e.g 37°C for amylase enzyme. Range of optimum temperature is 25–40°C.

9. Some enzymes are **intracellular** or **endoenzymes** (act within same cell) e.g. respiratory enzymes of mitochondria but some enzymes are **extracellular** or **exoenzymes** e.g. digestive enzymes of gastric glands, salivary glands and pancreas.

10. Enzymes have **high turnover number** (i.e. number of substrate molecules acted upon by one micromole of enzyme in one minute) or **katal number**. e.g. 5 million for **catalase,** 18 million for **urease,** 36 million for **carbonic anhydrase (fastest enzyme)**.

11. In metabolic pathways, enzymes act in a **specific sequence.**

12. Enzymes catalyse **reversible reactions.**

Enzymes v/s Inorganic catalysts.

Catalyst increases the rate of chemical reactions while enzyme enhances the rate of biochemical reactions. So, the enzymes are **biocatalysts.** Both have certain **similarities** in their characters e.g.

1. Both are effective in very small amounts.

2. Both remain unchanged in the reaction qualitatively as well as quantitatively.

3. Both ordinarily have no effect on equilibrium of reversible chemical reaction; they merely speed up the reaction until it reaches equilibrium.

4. They simply increase the rate of chemical or biochemical reactions by lowering the value of activation energy. It is important to note that they do not initiate the reaction.

5. These form short-lived complexes with substrate molecules.

Importance of Enzymes

A biological system needs the enzymes for two reasons :

1. Metabolic reactions proceed at **controlled temperature.**

2.These act as **biocatalysts** to speeden the rate of biological functions which otherwise would have been too slow to meet the energy needs of body e.g. in the absence of enzyme **carbonic anhydrase,** only 200 molecules of carbonic acid (H_2CO_3) are formed per hour by the dissolution of CO_2 in water while in the presence of enzyme, the reaction speeds up drammatically and about 600,000 molecules are formed every second. This proves that enzyme has accelerated the rate by about 10 million times.

$$\underset{\text{Carbon dioxide}}{CO_2} + \underset{\text{Water}}{H_2O} \xrightleftharpoons[\text{(in RBCs)}]{\text{Carbonic Anhydrase}} \underset{\text{Carbonic acid}}{H_2CO_3}$$

Similarly, one micromole of **urease enzyme** hydrolyses about 30,000 molecules of urea into carbon dioxide and ammonia in one second while in the absence of enzyme, same reaction will be completed in 3 million years.

MECHANISM OF ENZYME ACTION

(a) Lock and key mechanism (Fig. 33). Enzymes bear **distinct active centres** or **catalytic sites** or **active sites** in which specific types of substrate molecules can

Table 23. Differences between Inorganic catalysts and Enzymes.

Character	Inorganic catalysts	Enzymes
1. Nature	Catalysts are simple, small mineral ions.	Enzymes are made up of proteins which are highly complex having three dimensional shape.
2. Control	Their activity cannot be controlled by regulators.	Enzymatic activity can be controlled by use of certain regulators which can change the conformation of protein molecules.
3. Factors	Catalysts are not affected much by factors like pH and temperature.	Enzymes are highly sensitive to change in pH and temperature conditions.
4. Reactions	Catalysts can catalyse diverse reactions.	Enzymes act on specific reactions only.

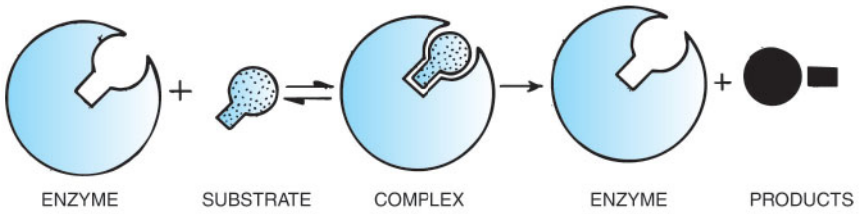


Fig. 33. Diagrammatic representation of interaction of enzyme and substrate.

form intimate association by their specific area called **reactive sites.** Because these active sites are specifically designed, only specific substrate molecules with proper geometric shape can fit correctly. This intermediate **enzyme-substrate complex** (ES-complex) soon breaks to release the enzyme and product of biochemical reaction. In certain reactions, ES-complex dissociates into products and enzyme through an intermediate and short-lived **Enzyme-product complex (EP)** which is a **transient phenomenon.** It is considered that when substrate molecule binds to the active site, its parts are held together in such a way to cause **distortion of chemical bonds** of substrate molecules *i.e.*, the bonds are weakened. These weakened bonds speed up the rate of reaction. The overall process can be summarised by the following reactions :

$$\text{Enzyme + Substrate} \longrightarrow \text{Enzyme substrate Complex} \downarrow \text{Enzyme + Product}$$

Active sites contain special groups having $—NH_2$, —COOH, —SH for establishing contact with substrate molecules. Because particular lock can be opened by a particular type of key and particular enzyme can act on particular substrate due to their specificity, the name for the mechanism has been given as **Lock and Key Mechanism** (**Fischer,** 1899).

(b) Induced fit mechanism (Fig. 34). It was put forward by **Koshland** in 1959. According to this theory, the active site of enzyme bears two groups: **buttressing** and **catalytic.**

The buttressing group supports the substrate. The catalytic group weakens the bond of reactants by electrophilic and nucleophilic processes. As soon as substrate comes in contact with buttressing group, the active site undergoes conformational changes. As a result catalytic group is brought opposite to those substrate bonds, finally to be broken. In this mechanism modification in the shape of active site occurs. Induced fit is possible because of the flexibility of the protein molecules.

(c) Michaelis-Menton hypothesis (Concept of Activation energy) (Fig. 35). All the chemical reactions have a potential energy barrier that must be overcome before the reactants (or substrates) are converted into end products. So the reactant molecules must be given sufficient energy to enter the reactive state, called **transition state,** which lies at the apex of the energy barrier.

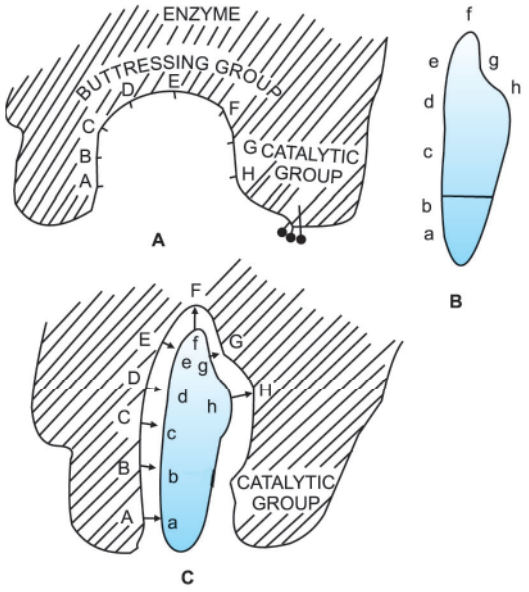


Fig. 34. Induced fit mechanism of enzyme action.

The minimum amount of energy required to bring the substrate molecules of one mole in the reactive form, is called activation energy. A comparison of the energy diagrams for catalysed and non-catalysed reactions **(Fig. 35)** shows that there is no difference in the energy of the reactants and products. This confirmed that enzyme does not change the thermodynamics of the system but changes the pathway of reaching the final state.

Michaelis and Menton (1913) explained the mode of action of enzymes on the basis of **activation energy.** They proposed that in an uncatalysed reaction, the number of substrate molecules in transition state are less so the rate of reaction is low, but the presence of enzyme lowers the energy barrier so more and more substrate molecules become reactive and react to produce the end products so increasing the reaction rate.

So the enzyme provides an **alternative pathway** for the chemical reaction **whose energy barrier is lower** so requiring less activation energy e.g. activation energy required for the decomposition of H_2O_2 in the absence of catalase enzyme is 18 Kcal./mole while in the presence of catalase, it is only 6.4 Kcal/mole.

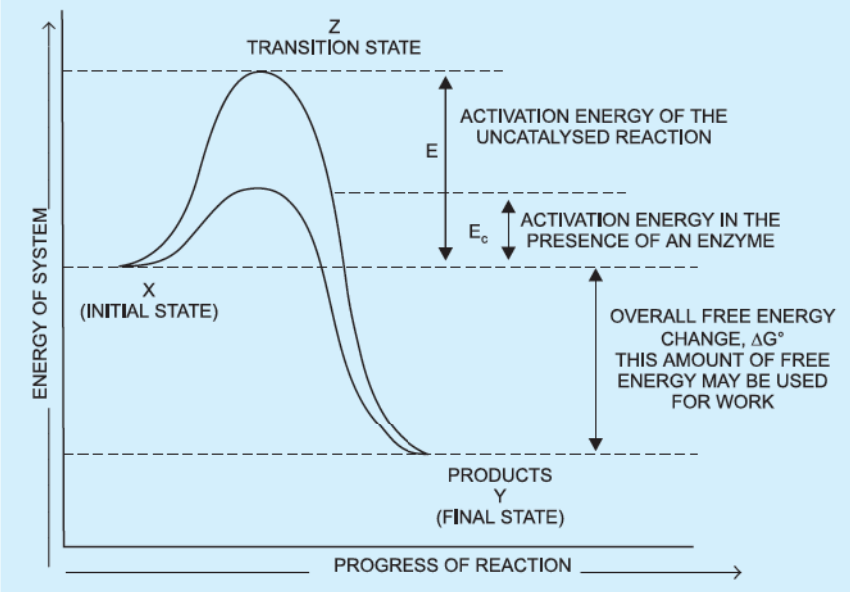


Fig. 35. Energy profile for uncatalyzed and enzymic reactions.

Factors affecting Enzyme activity

A number of external factor affect the tertiary structure so alter the activity of enzymes e.g.

1. Temperature (Fig. 36). Enzymes are **temperature specific** as each enzyme is most active at a specific temperature called **optimum temperature** e.g. 37°C for amylase. Range of optimum temperature is 25-40°C. Any increase or decrease in temperature than the optimum temperature decreases the enzyme activity so always exhibit **bell-shaped graph**. Generally the enzyme activity increases from 5°C to optimal temperature and doubles with every 10°C rise in temperature. This is called **temperature coefficient** (Q). This shows that **Q10 for most of enzymes is 2.** But very high temperature causes sudden fall in enzyme activity due to loss of tertiary structure of enzymes due to breaking of H-bonds and disulphide bonds. This is called **denaturation of enzymes.**

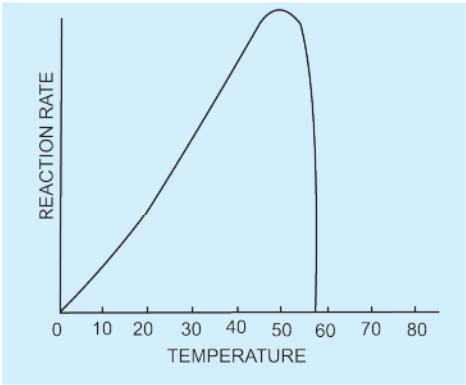


Fig. 36. Effect of temperature on enzyme activity.

This shows that in most of organisms, enzymes are **thermolabile** *i.e.* very sensitive to changes in temperature. But the enzymes of thermophilic organisms living under extremely high temperatures (e.g. bacteria found in hot springs) are highly heat resistant (upto 80–90°C) and show **thermal stability.**

2. pH (Fig. 37). Each enzyme functions most efficiently at a particular hydrogen ion concentration called **optimum pH** which generally lies in the range of 6.0–7.5 pH. Some enzymes work at low pH (e.g. pepsin of gastric juice = 2 pH) while some enzymes are active a high pH (e.g. trypsin of pancreatic juice = 8.8 pH). But some enzymes operate maximally at neutrality e.g. Amylase (6.8 pH), urease (7.0) and catalase (7.0 pH). It is suggested that hydrogen ion concentration causes changes in the ionization and solubility of enzymes, the substrates, inhibitors and even the activators. Graph of enzyme activity for its pH is always **bell-shaped**.

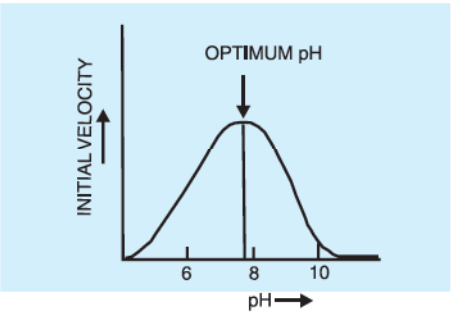


Fig. 37. Effect of pH on enzyme activity.

3. Substrate concentration (Fig. 38). At high enzyme concentration, increase in substrate concentration increases the rate a reaction upto a level. This is because more and more active sites of the enzyme molecules will be occupied by the substrate molecules. This continues till all the active sites are occupied by the substrate molecules and is called **saturation of enzymes.** Further increase in substrate concentration does not increase the rate of reaction. The stage of maximum velocity of chemical reaction is called **V. max.**

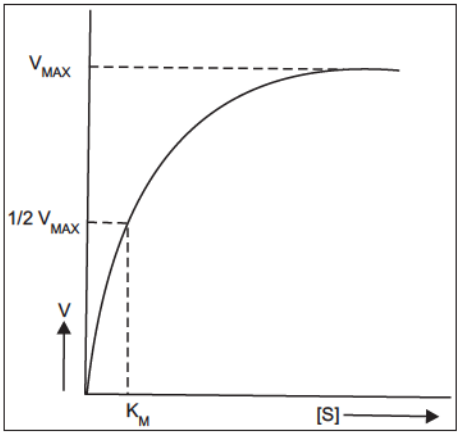


Fig. 38. Effect of substrate concentration on enzyme activity.

4. Presence of inhibitors. Inhibitors are those chemical compounds which decrease or stop the biological activity of the enzymes while this phenomenon is called **inhibition.** It is of following types :

(i) Competitive inhibition (Fig. 39A). In this, the inhibitor molecules show **structural similarity to the substrate molecules** so both compete to bind at the active sites of the enzyme. When an inhibitor binds the active site, then stable **enzyme-inhibitor complex** is formed and enzyme activity is reduced.

Enzyme + Inhibitor ⟶ Enzyme Inhibitor Complex.

A classic example of competitive inhibition is **succinic acid dehydrogenase** which oxidises succinic acid to fumaric acid. If concentration of malonic acid, is added, the activity of succinic acid dehydrogenase decreases rapidly. Hence **malonic acid (Malonate) acts as competitive inhibitor** since it has structural resemblance to succinic acid. The competitive inhibition **can be reversed** by increasing the concentration of the substrate.

Competitive inhibitors are used to control the bacterial pathogens by using the **sulpha drugs** (e.g. **sulphanilamide**) which work as competitive inhibitors of folic acid synthesis in bacteria as they substitute ***p*-aminobenzoic acid.**

(ii) Non-competitive inhibition (Fig. 39B). Sometimes, the **inhibitor is not structurally similar to the substrate molecule** so there is no competition for active sites of enzyme by inhibitor and it fixes itself with some other site (called **allosteric site**)of enzyme. As a result, the physical structure of enzyme is altered. This fails to form enzyme substrate complex and reaction fails to occur.

In non-competitive inhibition, many enzymes can be poisoned. For example, **cyanide poisoning** results inhibition of cytochrome oxidase which is essential for nearly all mammalian cells. The non-competitive inhibition **cannot be reversed** by increasing the concentration of the substrate.

Classification of Enzymes

According to **IUB (International Union of Biochemists–1961) system of classification,** enzymes can be divided into **six classes** based on the **nature of reaction** as given in **Table 24.** Each class is divided into **subclasses,** each of which is divided into **sub-subclasses** in which specific enzymes have been numbered.

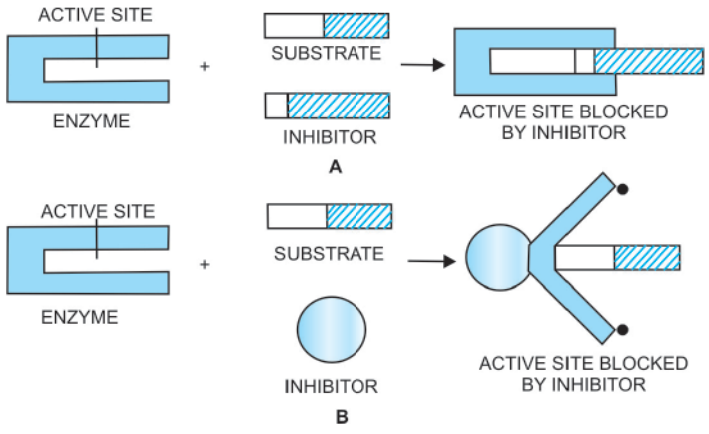


Fig. 39. A. Competitive inhibition; **B.** Non-competitive inhibition.

Table 24. International system of Enzyme-classification.

Class No.	Enzyme	Type of reaction catalyzed and example
1.	**Oxidoreductases**	Removing or adding electrons (or H^+) *i.e.* oxidation reduction reactions *e.g.* **cytochrome oxidase, alcohol dehydrogenase.** Ethanol + NAD $\underset{\text{DHase}}{\overset{\text{Alcohol}}{\rightleftharpoons}}$ Acetaldehyde + $NADH_2$
2.	**Transferases**	Transfer of functional group, carbon group, phosphate group, sulphur containing group *e.g.* glutamate pyruvate transaminase, hexokinase. Glucose + ATP $\overset{\text{Hexokinase}}{\rightleftharpoons}$ Glucose–6–P + ADP
3.	**Hydrolases**	Hydrolysis reactions *i.e.* breakdown by introduction of water and also breakdown of C-C, C-halide or P-N bonds *e.g.* digestive enzymes amylase, cellulase, sucrase etc. Sucrose + H_2O $\overset{\text{Sucrase}}{\rightleftharpoons}$ Glucose + Fructose
4.	**Lyases**	Catalyse the cleavage of specific covalent bonds and removal of groups without hydrolysis. They act on C-C, C-O, C-N, C-S and C-halide bonds *e.g.* histidine decarboxylase (acts on C-C bond in histidine to form CO_2 and histamine). Histidine $\underset{\text{decarboxylase}}{\overset{\text{Histidine}}{\rightleftharpoons}}$ Histamine + CO_2
5.	**Isomerases**	Isomerization reactions : catalyse the rearrangement of molecular structure to form isomers *e.g.* phosphohexoisomerase. Glucose-6-P $\overset{\text{Phosphogluco isomerase}}{\rightleftharpoons}$ Fructose-6-P
6.	**Ligases**	Formation of C-C, C-O, C-S, C-N, P-O, etc. bonds with ATP cleavage *e.g.* Pyruvate and CO_2 combines to form oxaloacetate in the presence of enzyme pyruvate carboxylase. Pyruvic acid + CO_2 $\overset{\text{Pyruvate carboxylase}}{\underset{\text{ATP}\quad\text{ADP + Pi}}{\rightleftharpoons}}$ Oxaloacetate

Nomenclature of enzymes

There are more than two thousand different enzymes in the living organisms which show great diversity in their biological control of metabolism. So, to differentiate these enzymes, their naming is must. There are several modes of nomenclature of enzymes **(Table 25)**:

Table 25. Modes of Nomenclature of enzymes.

Basis	Method	Enzyme name	Action
1. **On the basis of substrate**	By suffixing-**ase** after the substrate molecule.	**Sucrase**	Hydrolysis of sucrose.
		Lipase	Hydrolysis of lipids.
2. **On the basis of kind of reaction**	By suffixing-**ase** after the kind of reaction.	**Dehydrogenase**	Dehydrogenation.
		Oxidases	Oxidation.
		Decarboxylase	Removal of CO_2
3. **On the basis of their protein nature**	Enzyme name must end with "–in"	**Pepsin**	Proteins → Proteoses + Peptones
		Trypsin	Proteoses + Peptones → Peptides
		Ptyalin	Starch → Maltose
Out of these, ptylain has been renamed as **salivary amylase.**			
4. **On the basis of their source**		**Papain** from Papaya.	Splitting of peptide bonds.
5. **Latest method**	Enzyme name must be formed of 2 words : first word indicating substrate while second word indicating action.	**Glutamate-Pyruvate-transaminase**	Glutamate + Pyruvate ↓ α-ketoglutarate + Aspartate

COFACTORS

Definition. These are non-proteinous constituents of conjugated or compound enzymes which are associated with the proteinous apoenzyme of the enzyme and are essential for the catalytic activity of the holoenzyme. So the removal of cofactor causes the loss of enzyme activity.

Types of cofactors. Cofactors are divided into **three categories (Table 26)**:

Table 26. Three categories of Cofactors.

Cofactor type	Properties	Examples
1. Prosthetic groups	• These are always organic in nature. • Tightly bound to the apoenzyme.	**Haeme** is the prosthetic group and is part of active site of **catalase enzyme** which hydrolyses H_2O_2 : $2H_2O_2 \longrightarrow 2H_2O + O_2$
2. Coenzymes	• Always organic in nature. • Associated with apoenzyme only during the course of catalysis. • Generally derived from the vitamins. • Act as carriers of chemical groups or atoms or electrons.	**FAD** (from Riboflavin-B_2) for Succinate DHase. **NAD** (from Niacin-B_5) for Malate DHase. **TPP** (from Thiamine-B_1) for Decarboxylases.
3. Metal ions	• Always inorganic in nature. • Form a functional part of active site of enzyme. • Form coordination bonds with the side chains at the active sites.	**Mg^{++}** for hexokinase. **Zn^{++}** for carbonic anhydrase. **Cl^-** for α-Amylase. **Mo^{3+}** for Nitrogenase.

DID YOU KNOW?

- **J.B. Sumner** (1926) : Reported the proteinous nature of urease enzyme.
- A **holoenzyme** is always a conjugated protein. Its proteinous part is called **apoenzyme** while its non-proteinous part is called **cofactor.**
- Smallest enzyme is **peroxidase** while largest enzyme is **catalase.**
- Carbonic anhydrase is the **fastest** known enzyme while lysozyme is **slowest enzyme.**
- Enzymes generally function in a narrow range of temperature and pH.
- Denaturation of enzyme is a permanent phenomenon so it cannot be renatured.
- Very low temperature temporarily inactivates the enzymes and is a reversible phenomenon so enzyme activity is regained on increase in temperature.
- **Proenzymes** or **zymogens :** Inactive enzymes.
- **Michaelis constant (km) value** of an enzyme is the substrate concentration at which reaction rate is half of its maximum velocity. It is the measure of affinity of enzyme for the substrate.
- **Activators :** Those agents which activate the proenzymes e.g. activation of pepsinogen of gastric juice to active pepsin by H^+ of hydrochloric acid.
- **Autocatalysis :** When the end product start the activation of remaining proenzyme.
- **Enzyme code number :** A specific 4-digit number for a specific enzyme. e.g. Enzyme code no. of **ethanol dehydrogenase** is 1.1.1.1.
- Ribozymes were first reported by **Cech** *et.al.* (1981) in *Tetrahymena thermophila* (a ciliate protozoan).

PRACTICE PROBLEMS – ENZYMES

29. Name two non-proteinous enzymes.
30. Define turn over number.
31. Who proposed lock and key hypothesis of enzyme activity?
32. What do you mean by Km-value?
33. Define denaturation of enzymes.
34. Give one example of competitive inhibition.
35. List one difference between prosthetic group and coenzyme.

ANSWERS TO PRACTICE PROBLEMS

29. Ribozymes and RNAase-P in which RNA acts as biocatalyst.
30. Number of substrate molecules acted upon by one micromole of enzyme in one minute.
31. Emile Fischer.
32. It is that substrate concentration at which enzyme activity is half of V.max.
33. Permanent loss of tertiary structure and biological activity of enzyme at very high temperature.
34. Malonic acid shows competitive inhibition of enzyme Succinic DHase.
35. Prosthetic group is tightly bound to the apoenzyme e.g. haeme of catalase, while coenzyme is loosely associated to the apoenzyme at the time of catalysis e.g. FAD, NAD, etc.

ADDITIONAL USEFUL INFORMATIONS ABOUT BIOMOLECULES OF LIFE FOR COMPETITIVE EXAMINATIONS

- *Histidine and proline are **heterocyclic** amino acids.*
- ***Cholesterol** acts as precursor for bile salts and steroid hormones.*
- *Purines and pyrimidines are in equal ratio in DNA.*
- *Six protoplasmic elements having the importance in living organisms in decreasing order are C > H > O > N > S > P.*
- *Dumb-bell shaped starch grains are present in Euphorbia.*
- ***Paraffin wax** is not a wax. It is petroleum product. **Bees wax** has palmitic acid and myricyl alcohol.*
- *Honey bees inject formic acid (HCOOH) during their bites.*
- ***Saccharine** in cancer causing sugar.*
- ***Monellin** (200 times sweeter than sugar) is sweetest chemical and is a protein obtained from African berry.*
- ***Turpentine oil** is got from **Pinus.***
- *All proteinic amino acids are dextrorotatory in nature.*
- ***Immunoglobulins** or antibodies are proteins produced by lymphocytes.*
- ***P-protein** is a special protein present in phloem and plays important role in transport of nutrients.*
- *A protein having two or more polypeptides is called **oligomeric protein.***
- *Chitin, arabanogalactans, arabanoxylans are some examples of **heteropolysaccharides.***
- *Rapid cooling of the denaturated DNA fixes it in a permanently denatured state. It is called **quenching.***
- *Total quantity of DNA per genome of an organism is called **C value.** The C value is represented by picograms (pg) or base pair (pb). One pg = 0.965 × 10^9 pb.*
- *Smaller the Km greater the substrate affinity.*
- *Deficiency of an enzyme is called **enzymopenia.***
- *Enzyme that catalyses the conversion of soluble proteins into insoluble ones, process is called **enzyme coagulation.***
- *DEP **(Di isopropyl fluorophosphate)** inhibits the action of various enzymes catalysing hydrolysis of ester linkage.*
- *It is more difficult to denaturate the enzyme substrate complex than isolated enzyme.*
- *The ability of enzymes to recognise specific molecules means they can be used as **molecular probes** or **biosensor.** One of the biosensors developed uses the enzyme glucose oxidase. Such a biosensor is invaluable to people with diabetes who need to quickly and easily monitor their blood glucose levels.*
- *More then 500 metabolic pathways occur in liver.*
- *All components of cell including cell wall and cell membrane have enzymes.*
- *Maximum enzymes in the cell are found in mitochondrion.*

CHAPTER SUMMARY

- Alkaloids, flavonoids, rubber, essential oils, antibiotics, coloured pigments, scents, gums, spices are called **secondary metabolites.**
- Three different types of **bonds** occur in the formation of polymeric biomolecules-peptide, glycosidic and phosphodiester.
- **Carbohydrates** are polyhydroxy, aldehydes or ketones and their condensation products.
- **Monosaccharides** are simple reducing polyhydroxy sugar or ketone sugars or carbohydrate monomers which cannot be hydrolysed further into smaller subunits.
- **Polysaccharides** are complex long chain carbohydrates which are formed by polymerisation of more than ten units of monosaccharides'.
- **Glycogen** in glucose homopolyscaccharides which is major reserve food of animals and fungi.

- **Lipids** are formed of Carbon, Hydrogen, Oxygen where oxygen content is very small.
- Fatty acids are monocarboxylic organic acids (R. COOH) having a hydrocarbon chain of 1–19 carbon atoms with 1–3 (e.g. CH_3, C_2H_5, C_3H_7) not considered fatty acids.
- **Cholesterol** helps in the formation of bile salts and bile acids.
- **Amino acids** are aminated organic acids.
- **Proteins** are large sized mixed polymers of several types of α-amino acids joined by peptide linkage into linear chain which get folded variously.
- There are three types of proteins on the basis of shape-fibrous, globular and intermediate.
- On the basis of composition, proteins are of three types i.e. simple, conjugated and derived.
- Nucleotides are phosphorylated nucleosides.
- Cyclic AMP is technically adenosine 3, 5 monophosphate.
- **Nucleic acids** are linear mixed polymers of prime and pyrimidine nucleotides.

KEY TERMS

Active site	:	Catalytic site of enzyme at which substrate fits in.
Activation energy	:	Amount of energy required to bring one mole of substrate molecules in transition state.
Anabolism	:	Constructive or biosynthetic biological activities.
Apoenzyme	:	Proteinous part of a conjugated enzyme.
Bioenergetics	:	Energy transfer and transformation.
Biomacromolecules	:	Large sized biomolecules of cellular pool.
Catabolism	:	Sum of destructive biological activities.
Coenzyme	:	Organic compound loosely attached to apoenzyme of an enzyme.
Denaturation	:	Permanent loss of enzyme activity at high temperature.
Enzymes	:	Biocatalysts which increase the rate of biochemical reaction.
Essential amino acids	:	Cannot be synthesized in the body so must be taken in diet.
Heteropolymer	:	A polymer of two or more types of monomers.
Homopolymer	:	A polymer of similar monomers.
Inhibition	:	Decrease in enzyme activity in the presence of inhibitors.
Metabolism	:	Sum of all the body functions.
Nucleoside	:	Combination of a nitrogen base and a pentose sugar.
Nucleotide	:	Combination of a nucleoside and a phosphate group.
Primary metabolite	:	Chemical compounds of most of cellular cytoplasm.
Prosthetic group	:	Organic part tightly bound to an apoenzyme of an enzyme.
Secondary metabolites	:	Chemical compounds which are present only in certain specific cell types and have unknown functions.
Turn over	:	Change of biomolecules into one another.

NCERT FILE *Solved*

NCERT Exercise Questions

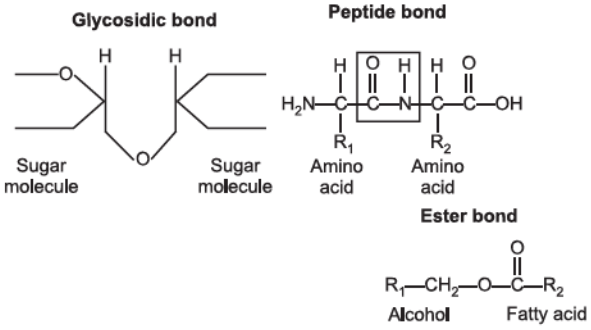
1. What are macromolecules? Give examples.

Ans. (i) **Macromolecules** are large-sized compounds with high molecular weight but poorly soluble in water. These are formed by condensation of micromolecules by dehydration synthesis.

(ii) **Examples:** Proteins, polysaccharides, nucleic acids, etc.

2. Illustrate a glycosidic, peptide and a phosphodiester bond.

Ans.



3. What is meant by tertiary structure of proteins?

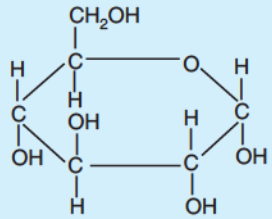
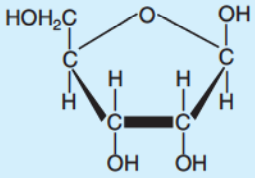
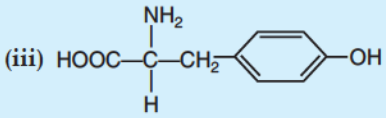
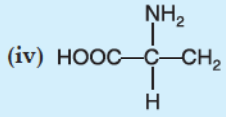
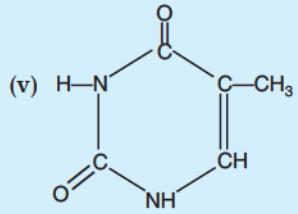
Ans. (i) A polypeptide chain is folded upon itself to form a **three-dimensional globular structure.**

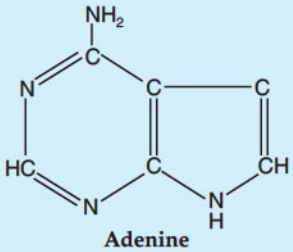
(ii) It is stabilized by **four types of bonds :** ionic bonds, H-bonds, hydrophobic bonds and disulphide bonds between different loops of same polypeptide chain.

(iii) **Examples :** All the enzymes, myoglobin of muscles, globulins of plasma, etc.

4. Find and write down structure of 10 interesting small molecular weight biomolecules. Find if there is any industry which manufactures the compounds by isolation. Find out who are the buyers?

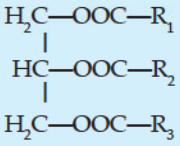
Ans. Small-sized biomolecules having low molecular weights are called **micro-biomolecules.** These include amino acids, mono sugars, triglycerides, phospholipids, cholesterol, nitrogen bases, nucleosides, nucleotides, etc.

Microbiomolecule	Significance
(i)  α—Glucose	• Glucose acts as **Chief respiratory fuel** in the body cells and provides about 60 per cent energy needs of man. • Glucose is the most important monomer of polysaccharides.
(ii)  Ribose	• Ribose acts as the component of Ribosides of RNA.
(iii)  Tyrosine	• Used in the formation of **thyroxine** and **adrenaline** hormones. • Used in the formation of **melanin** pigment.
(iv)  Glycine	• Used in the formation of **haeme.**
(v)  Thymine	• Component of deoxythymidylic acid (nucleotide) of **DNA.**

(vi) 

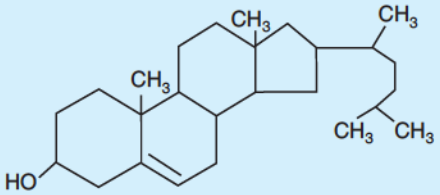
Adenine

- Component of both **DNA and RNA** nucleotides.
- Component of energy-rich **ATP** molecules.
- Component of H-carriers like **FAD and NAD.**

(vii) 

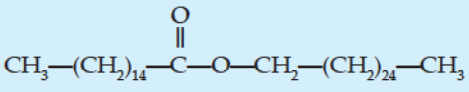
Triglyceride

- Triglycerides act as **concentrated respiratory fuel** as provide more energy than glucose on complete oxidation.

(viii) 

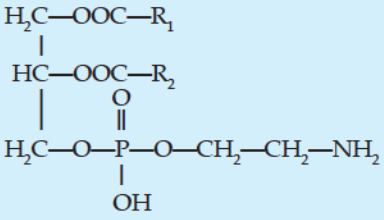
Cholesterol

- Precursor of **steroid hormones** like β-estradiol of ovary, testosterone of testis, etc.
- Participates in the formation of **medullary sheath.**

(ix) 

Bee wax

- Used in the formation of **bee waxes, polishes, candles,** etc.

(x) 

Cephalin (Phospholipid)

- Component of **medullary sheath** of nerve fibres.

5. Proteins have primary structure. If you are given a method to know which amino acid is at either of the two terminals (ends) of a protein, can you connect the information to purity or homogeneity of a protein?

Ans. In primary structure of a protein, amino acids show **linear arrangement.** To sequence an entire polypeptide chain, a chemical method, called **Edman degradation,** was devised by **Pehr Edman.** This procedure labels and removes only the amino-terminal residue from a polypeptide, leaving all other peptide bonds intact. So the amino acids are labelled, removed and identified one by one. By this method, we can connect the information to determine the homogeneity of a protein.

6. Find out and make a list of proteins used as therapeutic agents. Find other applications of proteins (e.g. cosmetics, etc.).

Ans.

(i) Therapeutic proteins		Antibodies, Thrombin, Fibrinogen, Monellin, ELISA, Renin, Insulin, Oxytocin, Vasopressin, Diastase, etc.
(ii) Other groups of proteins :		
(a) Structural proteins	:	Help in growth and repair of body tissues e.g. chondrin, ossein, tubulin, α-keratins, collagen, etc.
(b) Enzymatic proteins	:	Regulate the metabolic functions e.g. pepsin, trypsin, amylase, etc.
(c) Hormonal proteins	:	Regulate the metabolic functions e.g. parath-ormone, thyroxine, STH, etc.
(d) Contractile proteins	:	Help in movements and locomotion e.g. myosin, actin, etc.
(e) Transport proteins	:	Transportation of materials e.g. haemo-globin, carrier proteins, etc.

7. Explain the composition of a triglyceride.

Ans. A triglyceride is formed of one molecule of glycerol and three molecules of similar or different fatty acids. One fatty acid is attached to each of three —OH groups of glycerol by **ester bond** formed between hydroxyl group of glycerol and carboxyl group of the fatty acid by dehydration synthesis. Triglycerides may be pure e.g. **tripalmitin** and **tristearin;** or mixed e.g. **palmito-oleio-stearin.**

8. Can you describe what happens when milk is converted into curd or yoghurt; from your understanding of proteins?

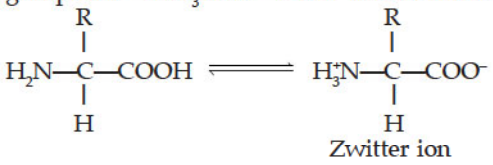
Ans. During bacterial fermentation of milk proteins, the bonds which maintain their secondary and tertiary structures are broken so the milk proteins (e.g. casein) undergo denaturation. Due to this, the globular proteins transform into fibrous proteins having only primary structure. This changes milk into curd or yoghurt.

9. Can you attempt building models of biomolecules by using commercially available atomic models (e.g. Ball and stick models).

Ans. Yes. The biomolecules can be represented by ball and stick models e.g. the basic structure of an amino acid can be represented as under :

10. Attempt titrating an amino acid against a weak base and discover the number of dissociable (ionizable) functional groups in the amino acid.

Ans. When an amino acid is dissolved in water, it exists as the dipolar ion or **zwitter ion** (i.e. hybrid ion) so can act as either an acid (proton donor) or a base (proton acceptor). This is because it has two ionizable groups i.e. $—NH_3^+$ and $—COO^-$ shown below :

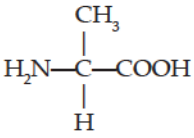


Zwitter ion

In some amino acids, R-group is non-ionizable e.g. **glycine,** but in some amino acids, even R-group is ionizable e.g. **Glutamic acid, histidine,** etc.

11. Draw the structure of the amino acid alanine.

Ans.



12. What are gums made of? Is Fevicol different?

Ans. **Gums** are natural heteropolysaccharides and are formed of large number of different monosaccharide units interlinked by glycosidic bonds. Fevicol is different from the gums as these are synthetic polymers.

13. Find out the qualitative test for proteins, fats and oils, amino acids and test any fruit juice, saliva, sweat and urine for them.

Ans.

Biomolecule	Test	Procedure	Observation
1. Proteins	Biuret test	To about 2 ml. of sample solution in a test tube, added 1 ml. of 5% aq. NaOH and then added 2 drops of 2% aq. $CuSO_4$. Allowed the test tube to stand for some time.	Blue-violet colouration appears.
2. Fats and oils	Sudan-Black-B test	About 1 ml. of fat solution or oil is added to 4 drops of Sudan Black-B in a test tube. Shake and poured the contents in a beaker containing distilled water.	Black-coloured fat droplets are seen on the surface of water.
3. Amino acids	Ninhydrin test	To about 3 ml. of sample solution in a test tube, added 0.5 ml. of 1% aq. solution of Ninhydrin and then heated to boiling.	Blue colouration appears.

14. Find out how much cellulose is made by all the plants in the biosphere and compare it with how much of paper is manufactured by man and hence what is the consumption of plant material by man annually. What a loss of vegetation?

Ans. About 100 billion tonnes of cellulose is prepared per year by the plants all over the world.

15. Describe the important properties of enzymes.

Ans. Refer pages 26 of chapter 9.

NCERT Exemplar Problems

A. MULTIPLE CHOICE QUESTIONS

1. It is said that elemental composition of living organisms and that of inanimate objects (like earth's crust) are similar in the sense that all the major elements are present in both. Then what would be the difference between these two groups? Choose a correct answer from among the following:

(a) Living organisms have more gold in them than inanimate objects

(b) Living organisms have more water in their body than inanimate objects
(c) Living organisms have more carbon, oxygen and hydrogen per unit mass than inanimate objects.
(d) Living organisms have more calcium in them inanimate

2. Many elements are found in living organisations either free or in the form of compounds. One of the following is not, found in living organisms.
(a) Silicon (b) Magnesium
(c) Iron (d) Sodium

3. Aminoacids as the name suggests, have both an amino group and a carboxyl group in their structure. In addition, all naturally occurring aminoacids (those which are found in proteins) are called L-aminoacids. From this, can you guess from which compound can the simplest aminoacid be made?
(a) Formic acid (b) Methane
(c) Phenol (d) Glycine

4. Many organic substances are negatively charged e.g., acetic acid, while others are positively charged e.g., ammonium ion. An aminoacid under certain conditions would have both positive and negative charges simultaneously in the same molecule. Such a form of aminoacid is called :
(a) Positively charged form
(b) Negatively charged form
(c) Neutral form
(d) Zwitterionic form

5. Sugars are technically called carbohydrates, referring to the fact that their formulae are only multiple of C (H_2O). Hexoses therefore have six carbons, twelve hydrogens and six oxygen atoms. Glucose is a hexose. Choose from among the following another hexose :
(a) Fructose (b) Erythrose
(c) Ribulose (d) Ribose

6. When you take cells or tissue pieces and grind them with an acid in a mortar and pestle, all the small biomolecules dissolve in the acid. Proteins, polysaccharides and nucleic acids are insoluble in mineral acid and get precipitated. The acid soluble compounds include aminoacids, nucleosides, small sugars etc. When one adds a phosphate group to a nucleoside one gets another acid soluble biomolecule called :
(a) Nitrogen base (b) Adenine
(c) Sugar phosphate (d) Nucleotide

7. When we homogenise any tissue in an acid the acid soluble pool represents :
(a) Cytoplasm (b) Cell membrane
(c) Nucleus (d) Mitochondria

8. The most abundant chemical in living organisms could be :
(a) Protein (b) Water
(c) Sugar (d) Nucleic acid

9. A homopolymer has only one type of building block called monomer repeated 'n' number of times. A heteropolymer has more than one type monomer. Proteins are heteropolymers made of aminoacids. While a nucleic acid like DNA and RNA is made of only 4 types of nucleotide monomers, proteins are made of :
(a) 20 types of monomers
(b) 40 types of monomers
(c) 3 types of monomers
(d) only one type of monomer

10. Proteins perform many physiological functions. For example, some functions as enzymes. One of the following represents an additional function that some proteins discharge :
(a) Antibiotics
(b) Pigments conferring colour to skin
(c) Pigments making colours of flowers
(d) Hormones

11. Glycogen is a homopolymer made of :
(a) Glucose units (b) Galactose units
(c) Ribose units (d) Aminoacids

12. The number of 'ends' in a glycogen molecule would be:
(a) Equal to the number of branches plus one
(b) Equal to the number of branch points
(c) One
(d) Two, one on the left side and another on the right side

13. A pure protein should normally have :
(a) Two ends (b) One end
(c) Three ends (d) No ends

14. Enzymes are biocatalysts. They catalyse biochemical reactions. In general they reduce activation energy of reactions. Many physico-chemical processes are enzyme mediated. Some examples of enzyme mediated reactions are given below. Tick the wrong entry :
(a) Dissolving CO_2 in water
(b) Untwining the two strands of DNA
(c) Hydrolysis of sucrose
(d) Formation of peptide bond

ANSWERS

1. (c);	2. (a);	3. (a);	4. (d);	5. (a);	6. (d);	7. (a);	8. (b);	9. (a);	10. (d);
11. (a);	12. (a);	13. (a);	14. (d).						

B. VERY SHORT ANSWER TYPE QUESTIONS

1. Medicines are either man made (i.e. synthetic) or obtained from living organisms like plants, bacteria, animals etc. and hence the latter are called natural products. Sometimes natural products are chemically altered by man to reduce toxically or side effects. Write against each of the following whether they were initially obtained as a natural product or as a synthetic chemical:

(a) **Penicillin** _____

(b) **Sulfonamide** _____

(c) **Vitamin C** _____

(d) **Growth Hormone** _____

Ans. (a) Penicillin : Natural

(b) Sulfonamide : Synthetic

(c) Vitamin C : Natural

(d) Growth Hormone : Natural

2. **Select an appropriate chemical bond among ester bond, glycosidic bond, peptide bond and hydrogen bond and write against each of the following:**

(a) **Polysaccharide** _____

(b) **Protein** _____

(c) **Fat** _____

(d) **Water** _____

Ans. (a) Polysaccharide : Glycosydic bond

(b) Protein : Peptide bond

(c) Fat : Ester bond

(d) Water : Hydrogen bond

3. **Write the name of any one amino acid, sugar, nucleotide and fatty acid.**

Ans. **Amino acid :** Glutamic acid

Sugar : Glucose

Nucleotide : Adenosine monophosphate (AMP)

Fatty acid : Linolenic acid

4. **Reaction given below is catalysed by oxidoreductase between two substances A and A,′ complete the reaction:**

A reduced + A′ oxidised ⟶

Ans. A reduced + A′ oxidised ⟶ A oxidised + A′ reduced.

5. **How are prosthetic groups different from cofactors?**

Ans. **Prosthetic group:** It is non-proteinaceous organic cofactor. It is strongly attached with apoenzyme. **Example:** Haeme in peroxidase and catalase.

Cofactor : In a holoenzyme or conjugate enzyme, cofactor is non-protein part which can be an inorganic ion, a prosthetic group or coenzyme.

6. **Glycine and alanine are different with respect to one substituent on the α-carbon. What are the other common substituent groups?**

Ans. The four substituent group present on four valency position of an amino acid are:

(a) Hydrogen (b) Carboxyl (c) Amino (d) Variable R group.

R group in glycine is –H. In alanine – H is substituted by $-CH_3$.

7. **Starch, Cellulose, Glycogen, Chitin are polysaccharides found among the following, Choose the one appropriate and write against each:**

(a) **Cotton fibre** : _____

(b) **Exoskeleton of cockroach** : _____

(c) **Liver** : _____

(d) **Peeled potato** : _____

Ans. (a) **Cotton fibre** : Cellulose

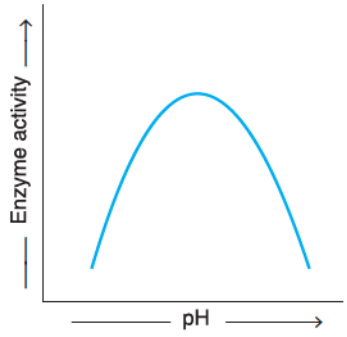
(b) **Exoskeleton of cockroach** : Chitin

(b) **Liver** : Glycogen

(c) **Peeled potato** : Starch

C. SHORT ANSWER TYPE QUESTIONS

1. **Enzymes are proteins. Proteins are long chains of aminoacids linked to each other by peptide bonds. Aminoacids have many functional groups in their structure. These functional groups are, many of them at least, ionisable. As they are weak acids and bases in chemical nature, this ionization is influenced by pH of the solution. For many enzymes, activity is influenced by surrounding pH. This is depicted in the curve below, explain briefly:**



Ans. Particular enzyme acts on a particular value pH when specific side chains are ionised. Activity of enzyme gets reduced both below and above optimum value.

2. **Is rubber a primary metabolite or a secondary metabolite? Write four sentences about rubber.**

Ans. Rubber is a secondary metabolite.

(i) It is obtained from the rubber tree i.e. *Hevea brasiliensis*.

(ii) Natural rubber (cis -1, 4-polyisoprene) is obtained from latex, which is produced from laticiferous cells in phloem.

(iii) Latex is coagulated and vulcanised by heating with sulphur.

(iv) Rubber is polymeric and terpenoid and known for its elasticity and plasticity.

3. **Schematically represent, primary, secondary and tertiary structures of a hypothetical polymer say for example a protein.**

Ans. Refer page no. 12 to 13 of the chapter

4. **Nucleic acids exhibit secondary structure, justify with example.**

Ans. DNA is a helical, made up of two chains. In its primary structure nucleotides with the help of phosphodiester bond are joined. These chains are held by hydrogen bonds to form a plectonemic helix. At his stage, it represents a secondary structure.

5. **Comment on the statement "living state is a non-equilibrium steady state to be able to perform work."**

Ans. Various living organisms represent a steady state due to concentration of different biomolecules. Steady state is a non-equilibrium state. Organisms work continuously, due to this they fail to reach equilibrium. This is performed by energy, which is provided by metabolism.

D. LONG ANSWER TYPE QUESTIONS

1. **Formation of Enzyme-Substrate Complex (ES) is the first step in catalysed reactions. Describe the other steps till the formation of product.**

Ans. Refer 'Mechanism of Enzyme Action' of this chapter.

2. **What are the different classes of enzymes? Explain any two with the type of reaction they catalyse.**

Ans. Refer Table 24 and 'Classification of Enzymes' of this chapter.

3. **Nucleic acids exhibit secondary structure. Describe through Watson & Crick model.**

Ans. Refer 'Nucleic acids' Q.4 of Short Answer Questions of this chapter.

4. **What is the difference between a nucleotide and a nucleoside? Give two examples of each with their structurer.**

Ans. Refer 'Nucleotides' of this chapter.

5. **Describe various forms of lipid with few examples.**

Ans. Refer 'Lipids' of this chapter.

HOTS Higher Order Thinking Skills & Brain Twisting

QUESTIONS WITH ANSWERS

Very Short Answer Questions *One mark each*

1. **What is the composition of triglyceride ?**

Ans. A triglyceride bears one molecule of glycerol esterified with three molecules of fatty acids.

2. **Name the chemical used for grinding the animal tissue for chemical analysis of organic compounds.**

Ans. Trichloroacetic acid.

3. **Name the (a) Fruit sugar (b) Blood sugar (c) Milk Sugar (d) Cane sugar**

Ans. (a) **Fruit sugar :** Fructose ; (b) **Blood sugar :** Glucose (c) **Milk Sugar :** Lactose ; (d) **Cane sugar :** Sucrose

4. **Name the amino acids involved in urea cycle.**

Ans. Ornithine, Citrulline (non-protein amino acids) and aspartic acid (protein amino acids).

5. **What are prostaglandins ?**

Ans. These are hormone like cellular messenger formed from unsaturated fatty acids like arachidonic acid.

6. **Sucrose is a non-reducing sugar. Maltose and lactose are reducing sugars. Why ?**

Ans. Sucrose does not bear free aldehyde or ketose group. On the other hand, it is present in maltose and lactose.

7. **Write two uses of cellulose.**

Ans. (i) Paper making (ii) Main constituent of cotton fibre.

8. **Which homopolysaccharide is called animal starch ?**

Ans. Glycogen.

9. **Name the polymer of fructose.**

Ans. Insulin.

10. **Name one heteropolysaccharide.**

Ans. Chitin

11. **Who proposed the lock and key hypothesis ?**

Ans. Emil Fischer (1894)

12. **What is the chemical nature of enzymes ?**

Ans. Enzymes are made up of proteins.

Short Answer Questions *Two marks each*

1. **What would happen if salivary amylase which acts specifically on starch enters the stomach and mixes with gastric juice ?**

Ans. In mouth starch forms maltose in presence of salivary amylase. Amylase stops working in stomach as it fails to act in acidic medium.

2. Write the forms representation of rate of chemical reaction. Define.

Ans. Rate = $\frac{dp}{dt}$

Rate of chemical reaction refers to amount of product formed per unit time.

3. Why starch and glycogen are more suitable as storage product than glucose ?

Ans. Starch and glycogen occupy less space and are less bulky. Whenever needed, they can be hydrolysed to glucose.

4. How do proteins act as carrier proteins ?

Ans. (i) They bind and transport specific molecules across the membrane. (ii) Haemoglobin of RBC in able to transport oxygen. (iii) Serum albumin transports fatty acids and lipids in the blood.

5. What is cholesterol ? Name the two forms of cholesterol.

Ans. It is a common sterol and the parent compound for steroid hormones. Low density cholesterol (LDL) is harmful and high density cholesterol (HDL) is useful and essential for many physiological processes.

6. What are pyrimidines ?

Ans. Pyrimidines are smaller sized nitrogen bearing biomolecules. They are 6 membered and bear one ring. It has nitrogen atoms at two places 1 and 5 e.g. cytosine, thymine and uracil.

7. What is peptide bond ?

Ans. This bond is formed between two amino acids by dehydrate synthesis between $-NH_2$ group of one and –COOH group of other amino acid. Peptide bond (–NH.CO–).

8. Name the essential fatty acids.

Ans. Linoleic acid, linolenic acid and arachidonic acid.

9. What are polyunsaturates ?

Ans. They are fatty acids with more than one double bond.

10. What are globular proteins ?

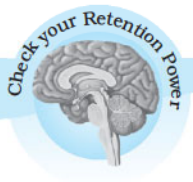
Ans. They are rounded proteins which are formed by tertiary and quaternary folding of polypeptides e.g. egg albumin.

Short Answer Questions *Three marks each*

1. How does temperature and pH affect activity of enzyme ?
2. Differentiate between prosthetic group and cofactor.
3. What are the factors which affect the action of enzyme ?
4. Differentiate between α-helix and β pleated structure of proteins.
5. Describe the composition of triglycerides.
6. Differentiate between primary metabolites and secondary metabolites.
7. What are gums made of ? Is fevicol different ?

Long Answer Questions *Five marks each*

1. What is the concept of metabolism ? Discuss the metabolic basis of life.
2. Write the functions of polysaccharides.
3. Differentiate between DNA and RNA.
4. Explain different classes of enzymes ? Explain any two with the type of reaction, they catalyze.
5. Discuss the tertiary structure of proteins.



QUICK MEMORY TEST

A. Say True or False

Write "True" or "False".

1. Proteins are one of the most diverse molecules of cell.
2. Oval and eccentric starch grains are found in maize.
3. FMN is related with vitamin B_2.
4. Duplication of DNA is called replication.
5. Adrenylic acid is an acidic amino acid.

6. Tryptophan takes part in the formation of vitamin nicotinamide.
7. Cephalin is found in liver.
8. In a nucleotide, purine or pyrimidine nitrogenous base is joined by deoxyribose sugar which is further linked to phosphate.
9. Bees wax consists of palmitic acid and myricyl alcohol.
10. As compared to carbohydrates, the amount of oxygen is high in lipids.
11. Gliadin protein found in wheat has the structure $C_{685}H_{1068}N_{195}O_{211}S_5$.
12. Glucose, fructose and lactose are isomers having a formula $C_6H_{12}O_6$.
13. Amino acids can be acidic, basic or neutral.
14. Oil dissolves in water.
15. Z-DNA has left handed helical structure as against right handed helical structure of B—DNA.
16. Waxes are long chain compounds belonging to class of esters.
17. Thyroxine is derived from tyrosine.
18. Removal of amino group from amino acids in animals is carried out by transamination only.

B. Complete the missing links

1. Fats are made of ..... and ..... .
2. ..... and ..... are purine nitrogenous bases.
3. ..... is cofactor in enzyme cytochrome oxidase.
4. A true fat with three molecules of fatty acids is called ..... .
5. Three pyrimidines are thymine, cytosine and ..... .
6. DNA has ..... instead of uracil.
7. rRNA is associated with ..... .
8. Keratin is a ..... protein.
9. Double helical structure is found in ..... .
10. The carbohydrate molecule cellulose is a ..... .
11. The double helix model of DNA was proposed by ..... and ..... .
12. .....and ..... are storage polysaccharides.
13. When amino acid chain is arranged like a coil, it is called an α ..... .
14. Chitin is a polysaccharide found in the ..... of crabs and prawn etc.
15. The kind of protein which can enhance the efficiency of a biochemical reaction is called an .....
16. The substances which stop or slow down the reaction are called .....
17. A protein molecule has at least 200 to 300 ..... linkages.
18. The enzymes which break down proteins into amino acid molecules are called as ..... .
19. When the enzymes with slightly different molecular structure can also perform the identical activities, they are called as ..... .
20. When the production of the cell is inhibited by its own metabolites, this control is termed as ..... .
21. Biochemical reactions are regulated by catalysts called ..... .
22. A vitamin is often associated as a ..... with an enzyme.
23. The molecules on which enzymes act are known as ..... .
24. Enzymes which breakdown compounds without the involvement of water are called ..... .
25. A compound with almost similar structure to the substrate can act as a ..... .
26. The functions of enzymes is to lower the ..... of biochemical reactions.
27. The enzymatic activity stops due to ..... of enzymes at very high temperature.
28. The enzyme ..... catalyses the formation of glucose-6-phosphate from glucose and ATP.
29. ..... catalyse covalent bonding between two molecules to form a large molecule.

C. Choose the correct alternative

1. **Lyases/Ligases** perform breakdown reacting .
2. **Apoenzyme/coenzyme** is the non-protein part of conjugate enzyme.
3. Nucleoside is **basic/acidic** in reaction.
4. Proenzymes are **active/inactive** enzyme precursors.

5. **Glutelins/Prolamins** are soluble in dilute alkali or acid.
6. Active site in induced fit theory is **static/dynamic.**
7. Source of lactose is **milk/germinating seeds.**

Answers QUICK MEMORY TEST

A. Say True or False

1. True;	2. False;	3. True;	4. True;	5. False;	6. True;
7. False;	8. True;	9. True;	10. False;	11. True;	12. False;
13. True;	14. False;	15. True;	16. True;	17. True;	18. True.

B. Complete the missing links

1. Fatty acids, glycerol; **2.** Adenine, guanine; **3.** Copper; **4.** Triglyceride; **5.** Uracil; **6.** Thymine; **7.** Ribosomes; **8.** Fibrous; **9.** DNA; **10.** Homopolysaccharide; **11.** Watson, Crick; **12.** Starch, glycogen; **13.** Helix; **14.** Exoskeleton; **15.** Enzyme; **16.** Inhibitors; **17.** Peptide; **18.** Proteases; **19.** Isoenzymes; **20.** Feed back inhibition; **21.** Enzymes; **22.** Coenzymes; **23.** Substrates; **24.** Lyases; **25.** Competitive inhibitors; **26.** Energy barrier/activation energy; **27.** Denaturation; **28.** Hexokinase; **29.** Ligases.

C. Choose the correct alternative

1. Lyases; **2.** Coenzyme; **3.** Basic; **4.** Inactive; **5.** Glutelins; **6.** Dynamic; **7.** Milk.

REVISION EXERCISES

Very Short Answer Questions

One mark each

1. Which mineral deficiency causes goitre in man?
2. Name two steroid hormones.
3. What are steroids?
4. Which type of bonds are present between the nucleotides in DNA?
5. Name three essential amino acids.
6. Which proteins help in night vision and colour vision?
7. What is the basic structural unit of chitin?
8. Where we can find chitin?
9. Name two S-containing amino acids.
10. Which mineral helps the enzyme nitrogenase in nitrogen fixation?
11. Give H—O—H bond angle found in water.
12. Why does water behave as a dipolar ion?
13. Why does water have high boiling point?
14. Define Michaelis constant (km) of an enzyme.
15. Give an example of non-competitive inhibition.
16. Which enzyme converts glucose into ethyl alcohol?
17. Give the term for the energy required to initiate a biochemical reaction.
18. What are peptide bonds?
19. Write two functions of waxes.
20. Give technical words for acid-soluble and acid-insoluble fractions.
21. Name two acidic amino acids.
22. Give three examples of homo polysaccharides.
23. Which organic compound is commonly called animal starch?
24. Name the sugar present in RNA.

25. Name the nitrogen bases of DNA.
26. What do you mean by antiparallel nature of two chains of DNA.
27. Distinguish between prosthetic group and coenzyme.
28. Name the inactive form of pepsin.
29. Give one example of non-competitive inhibition.
30. Who coined the term enzyme for the first time?
31. Name the biomolecules present in the acid-insoluble fraction.
32. What do you mean by Zwitter ionic nature of amino acids?
33. In which ratio, C, H and O are found in the carbohydrates?
34. Name three components of a nucleotide.
35. Give examples of proteins which help in blood clotting at injury.
36. Select the wrongly matched pair from the following:

Collagen	Intercellular ground substance
Insulin	Hormone
Antibody	Sensory reception
Trypsin	Enzyme

(Kerala Board 2017)

ANSWERS

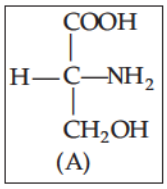
1. Iodine; **2.** Estrogens and testosterone; **3.** Organic compounds have sterol ring and fat-like properties; **4.** Phosphodiester bonds; **5.** Leucine, Lysine and phenylalanine; **6.** Rhodopsin (rod cells) and Iodopsin (cone cells); **7.** N-acetyl glucosamine; **8.** Cell wall of fungi and exoskeletal plates of arthropods; **9.** Cysteine and methionine; **10.** Molybdenum; **11.** 104.5°; **12.** It has electro-negativity on oxygen and electropositivity on hydrogen-atoms; **13.** Because different water molecules are inter linked by H-bonds; **14.** That substrate concentration at which reaction rate is half of maximum velocity; **15.** Cyanides inactivating cytochrome oxidases; **16.** Zymase; **17.** Activation energy; **18.** Bonds which interlink the amino acids and are formed by dehydration synthesis; **19.** (i) Form water proof coat on the leaves to reduce transpiration, (ii) Act as lubricants in the machine parts; **20.** Filtrate and retentate; **21.** Aspartate and Glutamate; **22.** Cellulose, starch and glycogen; **23.** Glycogen; **24.** Ribose; **25.** Adenine, Guanine, Cytosine and Thymine; **26.** 5′-3′ Phosphodiester sequence of two chains of DNA is opposite to each other; **27.** Prosthetic group is organic compound permanently and strongly bound to apoenzyme, while coenzyme is organic compound temporarily and loosely bound to apoenzyme; **28.** Pepsinogen; **29.** Cyanides inhibiting the activity of cytochrome oxidase; **30.** Edward Buchner; **31.** Proteins; polysaccharides, nucleic acids and lipids; **32.** Amino acid having +ve charge on $-NH_2$ group and –ve charge on - carboxyl group i.e. doubly charged ion; **33.** 1:2:1; **34.** Nitrogen base, pentose sugar and phosphate group; **35.** Prothrombin and fibrin; **36.** Antibody–sensory reception.

Short Answer Questions

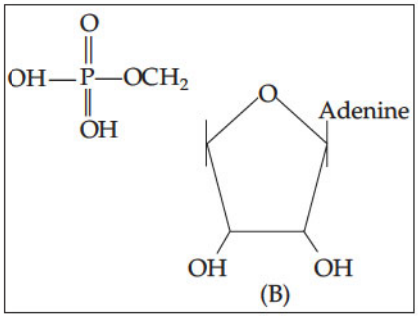
Two marks each

1. List four functions of proteins and name one protein which performs these functions each.
2. Proteins are known as biological polymers. Explain.
3. Why the starch and glycogen have been considered more suitable than to glucose as storage products.
4. Differentiate acidic and basic proteins.
5. What are xylan and inulin?
6. What is lignification?
7. "By his study of structure of protein molecules in living matter, the biologist sees very strong evidence of the unity in all living things. But he also sees the fundamental reason for most of the diversity in all living things." Analyse and explain these statements.
8. Explain the terms holozyme and isozyme.
9. Distinguish between apoenzyme and coenzyme.
10. Distinguish between co-enzyme and co-factor.
11. Name any three groups of digestive enzymes, their substrates and products.
12. Expand IUB and write about its most significant contribution.
13. How ferment and enzymes differ?
14. Discuss the statement : 'Organisms have biochemical adaptability to environment'.
15. Can a chemical reaction take place without enzyme? Comment.
16. What is a nucleotide?

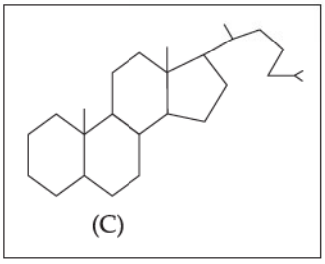
17. Differentiate between a nucleoside and a nucleotide.
18. Which type of bonds stabilize the tertiary structure of a protein?
19. Define Michaelis constant (Km) value of an enzyme.
20. Although all proteins are formed of same amino acids, explain how your proteins may be different from that of dog?
21. Distinguish between homopolysaccharides and heteropolysaccharides.
22. How do phospholipids differ from triglycerides?
23. What do you mean by holoenzymes?
24. Define turn over number. Give one example.
25. Differentiate between anabolism and catabolism.
26. Differentiate between primary and secondary structure of proteins.
27. Differentiate essential and non-essential amino acids.
28. What are derived fats? Give two examples.
29. Differentiate between primary and secondary metabolites.
30. Identify the given biomolecules: *(Kerala Board 2017)*



(A)



(B)


(C)

ANSWERS

1. **(a)** Protection and support e.g. keratin.
   (b) As oxygen carrier e.g. haemoglobin.
   (c) Food storage e.g. glutenin.
   (d) Catalytic e.g. enzymes.
2. Because proteins are polymers of amino acids and are able to perform multiple functions like protection, mechanical support, transportation, movement etc., they are also called as biological polymers.
3. These molecules become compact due to removal of water during polymerisation of glucose molecules and thus cover less space.
4. **Basic proteins.** A protein, rich in basic amino acids such as arginine and lysine, exists as a cation and behaves as a base at the physiological –pH of 7.4 is called basic protein. Examples histones of nucleoproteins of chromosomes.
   Acidic proteins. These are rich in acidic amino acids like glutamic acid and aspartic acid, and behave as acids (H-donors) at the physiological pH of 7.4.
5. **Xylan.** It is a hemicellulose and consists of D-xylose units linked through β-1, 4 glycosidic bonds.
   Inulin. It is a reserve carbohydrates of many plants. It contains 30 fructose units linked by 1-2 β linkage, has a molecular weight of about 5000. Fructose, a 6-carbon sugar, is present in 5-membered furanose ring form in inulin.
6. **Lignification.** Certain plant cells, notably those concerned with providing strength and conducting water, become lignified (converted into wood) during their development. In this process **lignin**, a polymer of various alcohol derivatives, is deposited in the spaces between the sugar molecules, making the cell wall much more rigid and rendering it impermeable. It thus serves as a water proof cement.

7. A knowledge of the structure of protein molecules provides strong evidence for the unity within the biosphere simply because the basic structural plan is repeated over and over in various combinations to form practicaly all the proteins in the living matter. But because the 20 amino acids are linked in different sequences, each protein will have its own unique characteristics. Therein lies most of the diversity within the biosphere. Each individual has unique proteins, and therefore one can expect an individual to have unique characteristics. This is diversity.
8. **Holozyme.** An enzyme and a coenzyme together form an enzymatically active conjugated protein called **holozyme.** The enzyme (protein) component is called **apoenzyme** and non-protein co-enzyme is called **prosthetic group. (Holozyme = Apoenzyme + Prosthetic group).**

   Isozyme. Different molecular species of an enzyme have the same function, such enzymes which exist in more than one form are called **isozymes.** They may be **homologous or analogous isozymes.** Homologous isozymes have similar molecular structure and catalytic property, while the analogous isozymes have similar reaction but different molecular structure and catalytic properties.
9. **Apoenzyme and Co-enzyme.** Although enzymes are **proteins** other molecules are often required for the proteins to show enzymatic activity which are called as **co-enzymes** and the actual protein components are known as **apoenzymes. Co-enzymes** are of low molecular weight and heat stable. The **apoenzyme** (proteins) have higher molecular weight and undergo denaturation at temperature of 50 – 60°°C.
10. **Co-enzyme and Co-factor.** When the prosthetics groups required to activate the action of an enzyme is **simple metal ion** such as Mg^{++} or K^{+}, they are called as **co-factor** and if it is organic ompound it is **co-enzyme. NAD, NADP** and certain vitamins are examples of co-enzymes.
11. (i) **Amylolytic enzymes.** These enzymes such as a Amylase, Maltase, Lactase, Sucrase act on complex **carbohydrates** and form diffusible **glucose.**

    (ii) **Proteolytic enzymes.** These enzymes such as Pepsin, Trypsin, Chymotrypsin and Erepsin act on **proteins** and convert them into **amino acids.**

    (iii) **Lipolytic enzymes.** These enzymes hydrolyse the ester bonds of lipids and convert them into glycerol and fatty acids e.g. lipase.
12. International union of biochemists. It has classified enzymes into six classes.
13. Ferment term was coined by Louis Paster and enzyme term was given by Buchner. There is no basic difference between the two terms.
14. Organisms can tolerate the varying environmental conditions e.g. algae found in hot water springs survive.
15. Yes, but slowly. However rate of reaction may not be able to sustain life.
16. A nucleotide is the monomer of nucleic acids (DNA and RNA) and is formed of a nitrogen base, a pentose sugar and a phosphate group.
17. A **nucleoside** is the combination of nitrogen base and pentose sugar e.g. Adenosine, while a **nucleotide** is formed of a nucleoside and a phosphate group e.g. Adenylic acid.
18. H-bonds, disulphide bonds, ionic bonds and hydrophobic forces of attraction.
19. Michaelis constant (Km) is the substrate concentration at which the enzymatic activity is half of V.max.
20. Different proteins show species specificity i.e. their own specific sequence of amino acids. The various premutations and combinations of these amino acids allow the synthesis of the large number of proteins having different nature and function.
21. Homopolysaccharides are formed of only one type of monosaccharides e.g. cellulose, starch, glycogen, etc. while heteropolysaccharides are formed of two or more types of monosaccharides or sugar derivatives e.g. chitin, heparin, etc.
22. A **triglyceride** is formed of 3 molecules of similar or dissimilar fatty acids attached to different —OH groups of glycerol by ester bonds, while a **phospholipid** is formed of a glycerol, two molecules of fatty acids, a phosphate group and a nitrogen base.
23. A **holoenzyme** is a conjugated enzyme and is formed of a proteinous part called **apoenzyme** and a non-proteinous part called **cofactor.**
24. **Turn over number** is the number of substrate molecules acted by one mole of enzyme molecules per minute e.g. 36 million molecules of carbonic acid are formed by enzyme carbonic anhydrase enzyme in one minute.
25. **Anabolism** is the sum of building or constructive metabolic processes e.g. photosynthesis, while **catabolism** is the sum of break down or destructive metabolic processes e.g. respiration.
26. **Primary structure** of protein indicates linear arrangement of amino acids e.g. of insulin, while **secondary structure of protein** indicates spatial arrangement of amino acids e.g. α-helix protein of hair, nails, etc.
27. **Essential amino acids** cannot be synthesized inside the body so must be present in the diet e.g. Lysine, leucine, methionine, etc., while **non-essential amino acids** can be synthesized in the body e.g. Glycine, alanine, etc.
28. **Derived fats** are compounds formed by partial hydrolysis of lipids or compounds having fat-like properties e.g. fatty acids, steroids, etc.
29. **See Table 9 of the text.**
30. **A.** Amino acid; **B.** Ribonucleotide; **e.** Cholesterol.

Short Answer Questions

Three marks each

1. Differentiate between B-DNA and Z-DNA.
2. List the functions of amino acids.
3. Write a note on allosteric enzymes.
4. Differentiate between competitive and non-competitive inhibition.
5. Define metabolism. Give the role of ATP in metabolism.
6. Why are the fatty acids insoluble while their two-carbon counterpart acetic acid is highly soluble?
7. Describe the formation of a nucleotide.
8. Account for the followings :
   (i) Phospholipids form a bilayer in an aqueous medium.
   (ii) Amino acids are amphiteric in nature.
9. Explain the formation of phosphodiester bonds.
10. Describe the quaternary structure of haemoglobin.
11. Write short notes on :
    (i) Steroids (ii) Waxes.
12. Give the biological importance of polysaccharides.
13. Explain the composition of glycogen.
14. How do the substrate concentrations affect the enzyme activity?
15. Illustrate the concept of activation energy in the mechanism of enzyme action.

Long Answer Questions

Five marks each

1. Describe the structure and biological importance of water.
2. Enumerate the types of proteins on the basis of their shape and chemical nature.
3. Enumerate three types of non-genetic RNAs.
4. Define inhibition. Describe different types of inhibition of enzymes.
5. Define metabolism. Describe two types of metabolism. What is the role of enzymes in metabolism.
6. Give the biological importance of different types of minerals.
7. What are oligosaccharides? Give the structure of sucrose and lactose.
8. List the functions of lipids in a biological system.
9. Describe the basic structure, types and biological importance of amino acids.
10. Describe the types and biological importance of monosaccharides.
11. Describe the components and formation of a nucleotide.
12. Enumerate the structural models of the proteins.

COMPETITION FILE OBJECTIVE TYPE QUESTIONS

A. MULTIPLE CHOICE QUESTIONS (MCQs):

(From AIPMT & Other Competitive Examinations)

1. Name the elements which occur in nucleic acid macromolecule :
   (a) C, H, O, N, S (b) C, O, N, S (c) C, O, P, S
   (d) C, H, O, N, P (e) H, O, P *(Kerala PMT 2006)*
2. The simple polyhydroxy ketone molecule containing 3-7 carbons is a :
   (a) Disaccharide (b) Monosaccharide (c) Polysaccharide
   (d) Dipeptide (e) Polypeptide *(Kerala PMT 2006)*
3. In the double helix model of DNA, how far is each base pair from the next base pair?
   (a) 3.4 nm (b) 0.34 nm (c) 2.0 nm
   (d) 34 nm (e) 0.034 nm *(Kerala PMT 2006)*

4. Cellulose, the most important constituent of plant cell wall is made up of :
   (a) Branched chain of glucose molecules linked by α, 1, 6, glycosidic bond at the site of branching
   (b) Unbranched chain of glucose molecules linked by α, 1, 4, glycosidic bond
   (c) Branched chain of glucose molecules linked by β, 1, 4 glycosidic bond in straight chain and α, 1, 6 glycosidic bond at the site of branching
   (d) Unbranched chain of glucose molecules linked by β, 1, 4 glycosidic bond *(AIIMS 2007)*
5. Feed back inhibition of an enzymatic reaction is caused by :
   (a) Substrate (b) Enzyme (c) End product (d) Rise in temperature *(AFMC 2007)*
6. Coenzymes :
   (1) Act as a donor of groups of atoms added to the substrate
   (2) Act as acceptor of groups of atom removed from substrate
   (3) Cannot be easily separated from apoenzyme
   (4) Do not act as prosthetic groups
   Codes : **(a)** 1, 2 and 3 are correct **(b)** 1 and 2 are correct
   (c) 2 and 4 are correct **(d)** 1 and 3 are correct *(BHU 2007)*
7. A substance unrelated to substrate but capable of reversibly changing activity of enzyme by binding to a site other than active site is called :
   (a) Competitive inhibitor (b) Non-competitive inhibitor
   (c) Catalytic inhibitor (d) Allosteric modulator/inhibitor *(BHU 2007)*
8. The enzyme which combines with non-protein part to form a functional enzyme is known as :
   (a) Co-enzyme (b) Holoenzyme (c) Apoenzyme (d) Prosthetic group *(BVP 2007)*
9. A complex polysaccharide produced from sucrose by the bacterium *Leuconostoc mesenteroides* is :
   (a) Chitin (b) Starch (c) Cellulose (d) Dextran *(BVP 2007)*
10. Which of the following enzyme is used in making detergent?
    (a) Amylase (b) Cellulase (c) Protease (d) Peptidase *(DPMT 2007)*
11. Enzyme found functional in lysosome is :
    (a) Acid phosphatase (b) Basic phosphatase (c) Oxidoreductase (d) Lyases *(DPMT 2007)*
12. Enzymes, vitamins and hormones can be classified into a single category of biological chemicals, because all of these :
    (a) Enhance oxidative metabolism
    (b) Are conjugated proteins
    (c) Are exclusively synthesized in the body of a living organism at present
    (d) Help in regulating metabolism *(JIPMER 2007)*
13. Carbohydrates are most abundant biomolecules on earth are produced by :
    (a) All bacteria, fungi and algae (b) Fungi, algae and green plant cells
    (c) Some bacteria, algae and green plant cells (d) Viruses, fungi and bacteria *(JIPMER 2007)*
14. A competitive inhibitor of succinic dehydrogenase is :
    (a) α-ketoglutarate (b) Malate (c) Malonate (d) Oxaloacetate *(CBSE 2008)*
15. Which one of the following pairs of nitrogenous bases of nucleic acids, is wrongly matched with the category mentioned against it?
    (a) Guanine, Adenine – Purines (b) Adenine, Thymine – Purines
    (c) Thymine, Uracil – Pyrimidines (d) Uracil, Cytosine – Pyrimidines *(CBSE 2008)*
16. In the DNA molecule :
    (a) The proportion of Adenine in relation to Thymine varies with the organism
    (b) There are two strands which run antiparallel – one in 5′→ 3′ direction and other in 3′→ 5′
    (c) Total amount of purine nucleotides and pyrimidine nucleotides is not always equal
    (d) There are two strands which run parallel in the 5′→ 3′ direction *(CBSE 2008)*

17. Carbohydrates are commonly found as starch in the plant's storage organs. Which of the following five properties of starch (1–5) make it suitable as a storage material :

1. Easily translocated 2. Chemically non-reactive 3. Easily digested by animals
4. Osmotically inactive 5. Synthesized during photosynthesis

The useful properties are :

(a) 1, 3 and 5 (b) 1 and 5 (c) 2 and 3 (d) 2 and 4 ***(CBSE 2008)***

18. Which of the followings is not caused by deficiency of mineral?

(a) Chlorosis (b) Etiolation
(c) Shortening of internodes (d) Necrosis ***(Haryana PMT 2008)***

19. Consider the following statements :

1. Cutin is a fatty acid polymer 2. Starch is a fatty acid polymer
3. Sucrose is a monosaccharide 4. Maltose is a polymer of glucose

Codes : (a) 1, 2, 3 are correct (b) 1, 2 are correct
(c) 2 and 4 are correct (d) 1 and 4 are correct ***(BHU 2008)***

20. DNA can be :

1. A-DNA 2. B-DNA 3. Z-DNA 4. Y-DNA

Codes : (a) 1, 2, 3 are correct (b) 1 and 2 are correct
(c) 2 and 4 are correct (d) 1 and 3 are correct ***(BHU 2008)***

21. Match list-I and list-II and select the correct answer using the code :

List-I (Enzyme)	List-II (Enzyme function)
Ligase	Joins short segments of DNA together
DNA Polymerase	Cuts DNA at specific DNA sequence
Helicase	Breaks the hydrogen bonds between complementary pairs during DNA replication

Codes : (a) 1, 2, 3 are correct (b) 1 and 2 are correct
(c) 2 and 4 are correct (d) 1 and 3 are correct ***(BHU 2008)***

22. Which of the following statements is/are not true?

A. Glycerol is a 3-carbon alcohol with 3-OH groups which act as binding sites
B. Waxes are esters formed between a long chain alcohol and saturated fatty acids
C. Term protein was coined by Johannes Mulder
D. Agar is a indispensable polysaccharide and is a complex polymer of glucose and sulphur-containing carbohydrates

(a) A and C only (b) A and D only (c) A, B and D only
(d) A, C and D only (e) D only ***(Kerala PMT 2008)***

23. An example of feedback inhibition is :

(a) Cyanide action on cytochromes (b) Sulpha drug on folic acid synthesizing bacteria
(c) Allosteric inhibition of hexokinase by Glucose-6-P (d) Reaction between succinate and succinic dehydrogenase
(e) Inhibition of succinic dehydrogenase by malonate ***(Kerala PMT 2008)***

24. The haploid content of human DNA is :

(a) 3.3×10^9 bp (b) 3.3×10^9 kbp (c) 4.6×10^6 bp
(d) 48502 bp (e) 1.65×10^9 bp ***(Kerala PMT 2008)***

25. Most common monomer of carbohydrates is :

(a) Glucose (b) Fructose (c) Sucrose (d) Maltose ***(Orissa JEE 2008)***

26. Which one of the following is ss RNA?

(a) TMV (b) T_2-bacteriophage (c) Pox virus (d) $\phi \times 174$ ***(J&K CET 2008)***

27. Uracil is present in RNA at the place of :

(a) Adenine (b) Guanine (c) Cytosine (d) Thymine ***(J&K CET 2008)***

28. The enzyme that cuts DNA is :

(a) DNA-polymerase (b) DNA-lyase
(c) DNA-ligase (d) Restriction endonuclease ***(J&K CET 2008)***

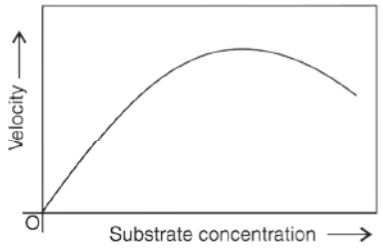
29. Which of the following is named for DNA produced from RNA?
(a) A-DNA (b) B-DNA (c) C-DNA (d) Z-DNA ***(WB-JEE 2008)***

30. Quaternary structure of protein :
(a) Consists of four subunits (b) May be either α or β-helix
(c) Is unrelated to the function of protein (d) Is dictated by the primary structure of the subunits ***(WB-JEE 2008)***

31. Identify the sulphur-containing amino acid?
(a) Proline (b) Methionine (c) Aspartic acid (d) Tryptophan ***(WB-JEE 2008)***

32. Which of the following carbohydrates is not a disaccharide?
(a) Maltose (b) Lactose (c) Sucrose (d) Galactose ***(WB-JEE 2008)***

33. The given graph shows the effect of substrate concentration on the rate of reaction of the enzyme green gram-phosphatase. What does the graph indicate?
(a) The rate of enzyme reaction is directly proportional to the substrate concentration
(b) Presence of an enzyme inhibitor in the reaction mixture
(c) Formation of an enzyme-substrate complex
(d) At higher substrate concentration the pH increases ***(AIIMS 2008)***



34. Enzymes that catalyse interconversion of optical, geometrical or positional isomers are :
(a) Ligases (b) Lyases (c) Hydrolases (d) Isomerases ***(DUMET 2009)***

35. The "lock and key" model of enzyme action illustrates that a particular enzyme molecule :
(a) May be destroyed or resynthesised several times
(b) Interacts with a specific type of substrate molecule
(c) Reacts at identical rates under all conditions
(d) Forms a permanent enzyme substrate complex ***(DUMET 2009)***

36. The effectiveness of an enzyme is affected least by :
(a) Temperature (b) Concentration of substrate
(c) Original activation energy of the system (d) Concentration of the enzyme ***(DUMET 2009)***

37. Starch is a polymer of :
(a) Glucose (b) Fructose (c) Sucrose (d) Maltose ***(UP-CPMT 2009)***

38. Table sugar is :
(a) Sucrose (b) Glucose (c) Fructose (d) Lactose ***(UP-CPMT 2009)***

39. Human proteins can be produced in the milk or semen of farm animals. True or false?
(a) True (b) False, proteins cannot be produced in milk
(c) False, proteins cannot be produced in semen (d) False, animals are not used for protein production ***(J&K 2012)***

40. ..... is a globular protein of ~6 kDa consisting of 51 amino acids, arranged in 2 polypeptide chains held together by disulphide bridge:
(a) Insulin (b) Keratin (c) Glucagon (d) Fibrinogen ***(AMU 2012)***

41. Match the items in column I with those in column II and choose the correct answer.

Column I (Biomolecules)	Column II (Examples)
(A) Carbohydrates	1. Trypsin
(B) Protein	2. Cholesterol
(C) Nucleic acid	3. Insulin
(D) Lipid	4. Adenylic acid

(a) A-3; B-1; C-4; D-2 (b) A-2; B-3; C-4; D-1 (c) A-3; B-4; C-1; D-2
(d) A-4; B-1; C-2; D-3 (e) A-1; B-2; C-3; D-4 ***(Kerala 2012)***

42. Match the following and choose the correct combination from the options given:

Column I (Organic compound)	Column II (Example)
(A) Fatty acid	1. Glutamic acid
(B) Phospholipid	2. Tryptophan
(C) Aromatic amino acid	3. Lecithin
(D) Acidic amino acid	4. Palmitic acid

(a) A-1; B-2; C-3; D-4 (b) A-4; B-3; C-2; D-1 (c) A-2; B-3; C-4; D-1
(d) A-3; B-4; C-1; D-2 (e) A-4; B-3; C-1; D-2 *(Kerala 2012)*

43. Select the option which is not correct with respect to enzyme action:
(a) A non-competitive inhibitor binds enzyme at a site distinct from that which binds the substrate
(b) Malonate is a competitive inhibitor of succinic dehydrogenase
(c) Substrate binds with enzyme at its active site
(d) Addition of lot of succinate does not reverse the inhibition of succinic dehydrogenase by malonate *(AIPMT 2014)*

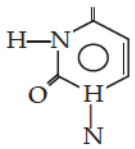
44. Which one of the following statements is not correct?
(a) Retinal is a derivative of vitamin C
(b) Rhodopsin is a purplish red protein present in rods only
(c) Retinal is the light absorbing protein of visual photopigment
(d) In retina, the rods have the photopigment rhodopsin, while cones have three different photopigments *(AIPMT 2014)*

45. Which one of the following is a non-reducing carbohydrate?
(a) Lactose (b) Ribose-5-phosphate (c) Maltose (d) Sucrose *(AIPMT 2014)*

46. The catalytic efficiency of two different enzymes can be compared by the :
(a) Molecular size of the enzymes (b) pH optimum values
(c) K_m values (d) Formation of the product *(J & K CET 2015)*

47. Which of the following is correct pair of pyrimidine bases ?
(a) Adenine and thymine (b) Adenine and guanine
(c) Thymine and cytosine (d) Guanine and cytosine *(Maharashtra CET 2015)*

48. Identify this structure :
(a) Adenylic acid
(b) Uracil
(c) Cholesterol
(d) Adenosine



(Karnataka CBT 2015)

49. This is a wax :
(a) Palmitic acid (b) Ethyl Palmitata
(c) Hexacosyl palmitate (d) Sodium stearate *(Bihar CECE 2015)*

50. A tripeptide contains :
(a) 3 amino acids (b) 4 amino acids
(c) 6 amino acids (d) 2 amino acids *(Bihar CECE 2015)*

51. How many phosphodiester bonds are there in ATP ?
(a) 3 (b) 2 (c) 1 (d) 0 *(Bihar CECE 2015)*

52. Which of the following bimolecules does have a phosphodiester bond ?
(a) Amino acids in a polypeptide (b) Nucleic acids in a nucleotides
(c) Fatty acids in a diglyceride (d) Monosaccharides in a polysaccharides *(AIPMT 2015)*

53. Which of the following biomolecules is common to respiration-mediated breakdown of fats, carbohydrates and proteins ?
(a) Pyruvic acid (b) Acetyl CoA
(c) Glucose-6-6 phosphates (d) Fructose 1, 6- bisphosphate *(NEET-II 2016)*

54. A typical fat molecule is made up of:
(a) Three glycerol molecules and one fatty acid molecule
(b) One glycerol and three fatty acid molecules
(c) One glycerol and one fatty acid molecule
(d) Three glycerol and three fatty acid molecules *(NEET-I 2016)*

55. The two functional groups, characteristic of sugars are:
(a) Carbonyl and methyl (b) Carbonyl and phosphate
(c) Hydroxyl and methyl (d) Carbonyl and hydroxyl *(NEET-I 2018)*

ANSWERS

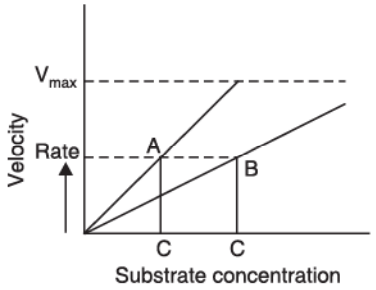
1. (d);	2. (b);	3. (b);	4. (d);	5. (c);	6. (b);	7. (d);	8. (c);	9. (d);	10. (c);
11. (d);	12. (e);	13. (c);	14. (a);	15. (a);	16. (a);	17. (d);	18. (d);	19. (c);	20. (d);
21. (b);	22. (d);	23. (b);	24. (d);	25. (b);	26. (c);	27. (a);	28. (a);	29. (d);	30. (c);
31. (b);	32. (d);	33. (b);	34. (d);	35. (b);	36. (d);	37. (a);	38. (a);	39. (a);	40. (a);
41. (a);	42. (b);	43. (d);	44. (a);	45. (d);	46. (c);	47. (c);	48. (b);	49. (c);	50. (a);
51. (d);	52. (b);	52. (b);	53. (b);	54. (b);	55. (b).				

B. CBSE - PMT (MAIN EXAMINATION) QUESTIONS :

1. **(i) Name three unusual bases present in tRNA and name the bases from which these are developed.**
(ii) Name 3 nucleotides which are not constituent of DNA/RNA but take part in metabolic activities. Also name their bases.
(iii) Name the achiral amino acid, symmetric with no side chain.
(iv) Name five amino acid with non-polar side chains. *(CBSE 2004)*

Ans. **(i)** Unusual bases of tRNA :
(a) Pseudouridine – from Uracil
(b) Ionosine – from Adenine
(c) Dihydrouridine – from Uracil
(ii) (a) ATP contains Adenine.
(b) NAD contains Adenine
(c) FAD contains Adenine.
(iii) Glycine. It is simplest amino acid in which R is —H.
(iv) Alanine, valine, leucine, isoleucine and phenylalanine.

2. **Refer the graph of two enzymatic reactions and answer the following questions :**



(a) What is denoted by plot A?
(b) What is denoted by plot B?
(c) What is C? What is the difference between C of A & B.
(d) What is allosteric modulation? *(CBSE 2006)*

Ans. **(a)** Plot A denote the enzyme substrate reaction which is high after reaching its maximum velocity due to high affinity between them. The rate of reaction is at a rapid state as compared to B.
(b) In plot B, the rate of reaction is slow as compared to plot A due to less affinity of enzyme for the substrate, but the increase in enzyme concentration increases the rate of reaction by producing more active sites to the substrates.
(c) C is the Michaelis constant (Km). Km is the concentration of a substrate required in order for an enzyme to act at half of its maximum velocity (V_{max}). The Michaelis constant is the measure of the affinity of an enzyme for a substrate. In A there is a high affinity for substrate than the affinity of enzyme in B.
(d) **Allosteric modulation** is the regulation of an enzyme or protein by binding an effector molecule at the protein's allosteric site (that is, a site other than the protein's active site). Effectors that enhance the protein's activity are referred to as **allosteric activators,** whereas those that decrease the protein's activation are called **allosteric inhibitors.** The term allostery comes from the Greek *allos*, "other," and *stereos*, "shape," referring to the regulatory site of an allosteric protein's being separate from its active site. Allosteric regulation is a natural example of feedback control.

3. **Fill in the blanks :**
(i) Biomembrane consists of phospholipids which has one unit of ..... and two units of ..... and phosphate group
(ii) Enzymes are globular ..... and has clefts on their surface called ..... .
(iii) Most food stored in the higher plants is in the form of ..... but cell wall is made up of ..... *(CBSE 2006)*

Ans. **(i)** Nitrogen base like choline (polar head), fatty acids (non-polar tails).
(ii) Proteins, active sites.
(iii) Starch, cellulose.

4. **What is ribozyme? Who discovered it and in which organism?** *(CBSE 2008)*

Ans. Ribozyme is a type of enzyme in which RNA can catalyze changes in its own molecular structure. Common example of ribozymes is **RNAase-P** and **self splicing group-I intron** (It removes introns from newly synthesized RNA). Ribozyme was first discovered by **Cech** *et.al.* (1981) in a ciliate protozoan called *Tetrahymena thermophila.*

5. **Fill in the blanks :**
The activity of enzyme inhibited when modulators bind to it is known as ..... inhibition. *(CBSE 2008)*

Ans. Allosteric.

C. MATCHING TYPE QUESTIONS :

1. **Match the terms in Column A with suitable terms in Column B :**

Column A	Column B
(i) Heparin	(a) Nucleotide
(ii) Keratin	(b) Nucleoside
(iii) Thymidilic acid	(c) Purine
(iv) Uridine	(d) Pyrimidine
(v) Guanine	(e) Heteropolysaccharide
	(f) Fibrous protein

2. **Match the terms in Column A with suitable terms in Column B :**

Column A	Column B
(i) NAD	(a) Carbonic anhydrase
(ii) Zymase	(b) Competitive inhibitor
(iii) Histidine decarboxylases	(c) Proteases
(iv) Cyanide	(d) Lyases
(v) Malonate	(e) Buchner
(vi) Fastest enzyme	(f) Non-competitive inhibitor
	(g) Coenzyme

3. **Match the biological molecules listed under Column I with their biological functions listed under Column II. Choose the answer which gives the correct combination of the alphabets of the two columns :**

Column I (Biological molecules)	Column II (Biological function)
A. Glycogen	p. Hormone
B. Globulin	q. Biocatalyst
C. Steroids	r. Antibody
D. Thrombin	s. Storage product

(a) A = q, B = s, C = r, D = p **(b)** A = s, B = r, C = p, D = q
(c) A = r, B = q, C = s, D = p **(d)** A = s, B = q, C = p, D = r *(KCET 2001)*

4. **Match the biological molecules listed under Column I with their biological functions given under Column II. Choose the answer which gives the correct combination of alphabets of the two columns :**

Column I (Biological molecules)	Column II (Biological function)
A. Starch	p. Protein synthesis
B. Haemoglobin	q. Sex hormones
C. RNA	r. Storage product
D. Steroid	s. Transport of gases

(a) A = s, B = r, C = p, D = q **(b)** A = r, B = s, C = q, D = p
(c) A = r, B = p, C = s, D = q **(d)** A = r, B = s, C = p, D = q *(KCET 2004)*

5. **Match the items in Column-I with items in Column-II and choose the correct answer :**

Column-I	Column-II
(i) Triglyceride	(a) Animal hormones
(ii) Membrane lipid	(b) Feathers and leaves
(iii) Steroid	(c) Phospholipids
(iv) Wax	(d) Fat stored in the form of droplets

(a) (i) (d); (ii) (c); (iii) (a); (iv) (b) **(b)** (i) (b); (ii) (c); (iii) (d); (iv) (a)
(c) (i) (c); (ii) (d); (iii) (a); (iv) (b) **(d)** (i) (d); (ii) (a); (iii) (b); (iv) (c)
(e) (i) (d); (ii) (c); (iii) (b); (iv) (a) *(Kerala PMT 2006)*

ANSWERS

1. **(i)** (e);	**(ii)** (f);	**(iii)** (a);	**(iv)** (b);	**(v)** (c).	
2. **(i)** (g);	**(ii)** (e);	**(iii)** (d);	**(iv)** (f);	**(v)** (b);	**(vi)** (a).
3. (b).	**4.** (d).	**5.** (a).			

D. ASSERTION TYPE QUESTIONS :

The following questions consist of two statements each, printed as *Assertion* and *Reason*. While answering these questions, you are required to choose any one of the following four responses :
A. If both *Assertion* and *Reason* are true and the *Reason* is a correct explanation of the *Assertion*.
B. If both *Assertion* and *Reason* are true but *Reason* is not a correct explanation of the *Assertion*.
C. If *Assertion* is ture but the *Reason* is false.
D. If both *Assertion* and *Reason* are false.

1. Assertion : Glycerides are neutral or true fats.
Reason : These are esters of fatty acids with glycerol.
A **B** **C** **D**

2. Assertion : Proteins are linear polymers of long chains made up of amino acids.
Reason : Amino acids are called building blocks of proteins.
A **B** **C** **D**

3. Assertion : Cephalins are amino acids and on hydrolysis give ammonia and water.
Reason : Cephalins are hydrolysed with H_2SO_4 and HNO_3.
A **B** **C** **D**

4. Assertion : All enzymes are amino acids.
Reason : Proteins are formed of carboxylic acids.
A **B** **C** **D**

5. Assertion : LDH has five isoenzymes while α-amylase has sixteen isoenzymes.
Reason : Isoenzymes perform same function but occur in more than one form.
A **B** **C** **D**

6. Assertion : Enzymes are organic catalysts.
Reason : They catalyze the chemical reactions.
A **B** **C** **D**

7. Assertion : Oxidoreductases catalyze redox reactions.
Reason : Isomerases catalyze the isomeric changes.
A **B** **C** **D**

8. Assertion : Intake of excess of saturated fats should be avoided.
Reason : Saturated fats change into cholesterol which causes arteriosclerosis.
A **B** **C** **D**

9. Assertion : Oils have lower melting point.
Reason : Oils mostly contain saturated fatty acids.
A **B** **C** **D**

10. Assertion : Chitin is a heteropolysaccharide.
Reason : Chitin is a polymer of N-acetyl Glucosamine.
A **B** **C** **D**

11. Assertion : Very low temperature causes permanent denaturation of enzymes.
Reason : Very low temperature breaks the disulphide bonds of enzymes.
A **B** **C** **D**

12. Assertion : Phospholipids are called amphipathic compounds.
Reason : Each phospholipid is doubly charged compound.
A **B** **C** **D**

13. Assertion : The higher the turnover number, the more efficient the enzyme is.
Reason : The enzymes occur in minute amounts due to their high turnover numbers.
A **B** **C** **D**

14. **Assertion :** Nucleotides are the building blocks of nucleic acid.
Reason : Nucleotides are also components of energy carriers and coenzymes.
A B C D

15. **Assertion :** Coenzyme is a non-proteinous group without which certain enzymes are inactive or incomplete.
Reason : Coenzymes not only provide a point of attachment to the chemical group being transferred but also influence the properties of the group.
A B C D *(AIIMS 1999)*

16. **Assertion :** Carboxypeptidase is an exopeptidase.
Reason : It cleaves the N-terminal bond.
A B C D *(AIIMS 2004)*

17. **Assertion :** A coenzymes or metal ions that is very tightly bound to enzyme protein is ealled prosthetic group.
Reason : A complete, catalytically active enzyme together with its bound prosthetic group is called apoenzyme.
A B C D *(AIIMS 2004)*

ANSWERS

1. (A);	2. (A);	3. (D);	4. (D);	5. (A);	6. (C);
7. (B);	8. (A);	9. (C);	10. (A);	11. (D);	12. (C);
13. (A);	14. (B);	15. (A);	16. (C);	17. (C).	

E. REASONING TYPE QUESTIONS :

Give the reasons for the following statements :

1. Nucleotides are acidic in nature.
2. GC pair of DNA is more stable than AT pair.
3. At high temperature, the enzymes stop functioning.
4. Cholesterol and its esters are deposited in the arteries.
5. In human beings some essential amino acids are required.
6. The high boiling point of water is advantageous to living organisms.
7. Apoenzyme alone cannot function.
8. Co-enzyme can function in association with an apoenzyme.
9. End products are generally not produced more than their requirements.
10. Enzymes generally have different pH but same temperature optima.

ANSWERS

1. It is due to presence of negatively charged phosphate groups.
2. There are 3 H-bonds between GC pair but only two H-bonds between AT pair.
3. Enzymes are denatured due to loss of their tertiary structure.
4. Cholesterol and its esters form bonds with fats secreted by endothelium.
5. Essential amino acids cannot be synthesized inside the human body so must be supplied in diet.
6. The environment seldom reaches the boiling point of water.
7. Apoenzyme is inactive proteinous component of enzyme and needs cofactor for its functioning.
8. Coenzyme cannot function independently but functions with apoenzyme as it accepts the group of substrate removed by apoenzyme.
9. When formed at required level, end product acts as modulator and stops its own formation by feedback inhibition of enzyme.
10. Different enzymes can function only at specific pH.

F. ANALOGY TYPE QUESTIONS :

Note the relationship between the first two words and suggest a suitable word for the fourth place :

1. amino acid : protein :: nucleotides : .....
2. plants : starch :: mammals : .....
3. α-helix : protein :: double helix : .....
4. protein : peptide bonds :: polysaccharide : .....

5. microbiomolecules : filtrate :: macrobiomolecules : .....
6. anabolism : photosynthesis :: catabolism : .....
7. primary metabolite : amino acids :: secondary metabolite : .....
8. hexokinase : transferase :: amylase : .....
9. α-helix : secondary structure :: enzymes : .....
10. purine : guanine :: pyrimidine : .....

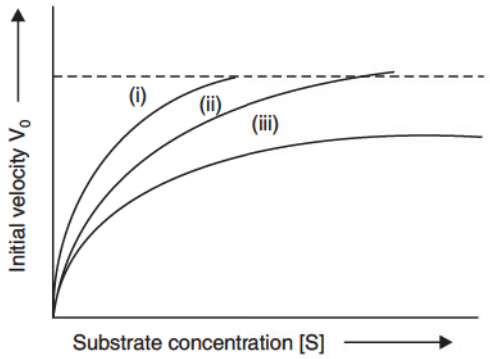
ANSWERS

1. Nucleic acids;	2. Glycogen;	3. DNA;	4. Glycosidic bonds;	5. Retentate;
6. Respiration;	7. Alkaloids;	8. Hydrolase;	9. Tertiary structure;	10. Thymine.

G. ADDITIONAL MULTIPLE CHOICE QUESTIONS :

Choose the correct answer :

1. Which is protein in nature?
   (a) Cellulose (b) Terylene (c) Polythene (d) Silk and wool
2. Which is a reducing sugar?
   (a) Cellulose (b) Maltose (c) Sucrose (d) Starch
3. Among following natural materials, largest amount of cellulose is found in :
   (a) Wood (b) Fruit pulp (c) Wheat straw (d) Cotton fibres
4. The polysaccharide formed from fructose monomers only is :
   (a) Inulin (b) Lignin (c) Cellulose (d) Amylose
5. An organic substance bound to an enzyme and essential for its activity is called :
   (a) Coenzyme (b) Holoenzyme (c) Apoenzyme (d) Isoenzyme
6. One turn of the helix in a B-form of DNA is approximately :
   (a) 20 nm (b) 0.34 nm (c) 3.4 nm (d) 2 nm
7. Anti parallel strands of a DNA molecule means that :
   (a) One strand turns anti-clockwise
   (b) One strand turns clockwise
   (c) Phosphate groups of two DNA strands at their ends, share the same position
   (d) Phosphate groups at the start of two DNA strands (poles) are in opposite position
8. In which one of the following sets of three items, each belong to the category mentioned against them?
   (a) Lysine, glycine, thiamine - amino acids
   (b) Myosin, oxytocin and gastrin - hormones
   (c) Rennin, helicase and hyaluronidase - enzymes
   (d) Optic, occulomotor, vagus - sensory nerves
9. The figure given below shows three velocity-substrate concentration curves for an enzyme reaction. What do the curves a, b, and c depict respectively.



(a) (i) normal enzyme reaction, (b) (i) enzyme with an allosteric modulator added,

(ii) competitive inhibition,
(iii) non-competitive inhibition

(c) (i) enzyme with an allosteric stimulator,
(ii) competitive inhibitor added,
(iii) normal enzyme reaction

(ii) normal enzyme activity,
(iii) competitive inhibition

(d) (i) normal enzyme reaction,
(ii) non-competitive inhibitor added,
(iii) allosteric inhibitor added

10. Chitin as exoskeleton is found in :
(a) *Periplaneta* (b) *Ascaris* (c) *Pheretima* (d) *Hydra*

11. Which enzyme converts glucose into alcohol?
(a) Zymase (b) Diastase (c) Invertase (d) Lipase

12. One mole of glucose on metabolism liberate how many kilo calories of energy?
(a) 180 (b) 80 (c) 160 (d) 280

13. Phosphodiester bond is present in :
(a) ATP (b) ADP (c) C-AMP (d) None of these

14. In which virus, DNA is double stranded?
(a) Hepatitis-A (b) Hepatitis-B (c) Hepatitis-C (d) Hepatitis-D

15. Which is the most abundant protein on earth?
(a) Lignin (b) Rubisco (c) Cellulose (d) Pectin

16. Essential amino acid which is synthesized by plant is :
(a) Phenylalanine (b) Leucine (c) Arginine (d) Serine

17. Enzyme responsible for conversion of glucose to C_2H_5OH is :
(a) Zymase (b) Invertase (c) Sucrase (d) Maltase

18. How many of the twenty two amino acids are essential amino acids for children?
(a) 6 (b) 8 (c) 10
(d) 7 (e) 11

19. The bacterial cell wall is formed of :
(a) Cellulose (b) Hemicellulose (c) Both (a) and (c)
(d) Peptidoglycan (e) Glycogen

20. Allosteric modulation is due to the inhibitory action of enzyme by :
(a) Competitive inhibition (b) Substrate concentration (c) Products of reaction
(d) Enzyme concentration (e) Non-competitive inhibition

ANSWERS

1. (d);	**2.** (b);	**3.** (d);	**4.** (a);	**5.** (a);	**6.** (c);	**7.** (d);	**8.** (c);	**9.** (d);	**10.** (a);
11. (a);	**12.** (d);	**13.** (d);	**14.** (b);	**15.** (b);	**16.** (a);	**17.** (a);	**18.** (c);	**19.** (d);	**20.** (c).

Chapter Practice Test

Time Allowed : 1:30 Hours *Maximum Marks : 35*

1. What is the sweetness index of sucrose ? (1)
2. Give two examples of storage polysaccharides. (1)
3. What is cellulose ? (1)
4. What is purine ? (1)
5. What is fat ? (1)
6. What are waxes ? (2)
7. A nitrogenous base is present in RNA but absent in DNA. Identify it. Where it exists ? (2)
8. Arrange following carbohydrates in order of increasing complexity.
   Starch, Fructose. Maltose, Oligosaccharide, Triose. (2)
9. Why proteins are called as biological polymers ? (2)
10. How does temperature offers the activity of enzyme ? (2)
11. What are the different levels of organisation of proteins ? (3)
12. Differentiate between anabolism and catabolism. (3)
13. Differentiate between homopolysaccharide and heteropolysaccharide. (3)
14. What are conjugated proteins? Give any three examples. (3)
15. Differentiate between saturated and unsaturated fatty acids. (3)
16. Describe the Watson and Crick model of DNA. (5)

❑❑❑

To check your performance, see ANSWERS TO CHAPTER PRACTICE TEST at the end of Part I of the book.

CHAPTER 10

CELL CYCLE AND CELL DIVISION

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CHAPTER PRACTICE TEST 37

INTRODUCTION

"**Continuity of life**" is an important characteristic of living organisms and is achieved through the process of reproduction. The reproduction may be **asexual** or **sexual**. Both of these involve the division and replication of cells. Even the **growth and development** of every living organism depends on the growth and division of its cells.

In **unicellular organisms**, cell division is the means of reproduction by which the mother cell produces two or more new cells. In multicellular organisms also, new individuals develop from a single cell—the **zygote**, by cell division. So by this process, the zygote is transformed into an adult formed of million or billion of cells. It also forms the basis of replacement of old and worn out cells in the process of repair and regeneration. **So, cell-division is central to life of the cell and is essential for the perpetuation of the species.**

TWO BASIC PROCESSES IN CELL REPRODUCTION

1. Cell-Growth (Period of synthesis and duplication of various components of cell).

2. Cell-Division (Adult cell divides into two daughter cells).

CELL CYCLE (FIG. 1)

1. Definition. All those changes which occur during cell-growth and cell-division are collectively called Cell cycle. It is the sum of all those events by which a cell duplicates its genome and synthesizes cell contents and eventually divides into two daughter cells. These events are themselves under genetic control.

2. Two parts of Cell cycle :

A. Interphase. B. M-phase.

A. Interphase. It is the period between the end of one cell division to the beginning of next cell division so is also called **intermitosis**. It is misnomerly called **resting phase** (no visible changes occur) but is actually highly **metabolically active phase or energy phase** in which cell prepares itself for next cell division by a number of biosynthetic activities, so is also called **preparatory phase.** Interphase lasts for about 95% (90 – 96%) of cell cycle.

On the basis of **synthetic activities**, interphase is divided into **three sub-phases :**

(a) G_1 or Gap - I or Post-mitotic or Pre-synthetic phase or First growth phase

It is the period between mitosis and initiation of DNA replication. It is characterized by increase in cell size and nucleus due to high rate of biosynthesis. It involves :

(i) Pooling of **amino acids** for protein synthesis.

(ii) Pooling of **nucleotides** for the synthesis of RNA and DNA.

(iii) Synthesis of **enzymes** (proteins) **and energy molecules** to unzip and synthesize DNA molecules.

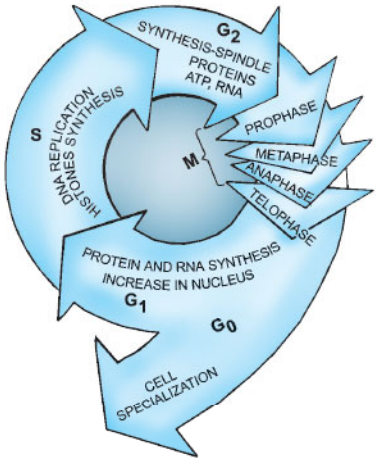


Fig. 1. Mitotic cell cycle.

(iv) Synthesis of macromolecules like RNAs, carbohydrates, lipids and proteins as the cell is metabolically active.

(v) Chromosome are fully extended. But no DNA duplication occurs.

(b) S or Synthetic phase. It is characterized by :

(i) DNA replicates so each chromosome is formed of **two sister-chromatids** joined at centromere.

(ii) Synthesis of **histones** (basic proteins).

Each cell is with double the amount (4C) of DNA **but the chromosome number remains same.**

(c) G_2 or Gap-II or Post-synthetic or Pre-mitotic phase or Second growth phase. It is characterized by increased nuclear volume. It involves :

(i) Synthesis of **spindle proteins.**

(ii) Synthesis of three types of **RNA molecules.**

(iii) Synthesis and storage of **ATP molecules.**

(iv) Duplication of **mitochondria, plastids** and **centrioles.**

(v) Damaged DNA is repaired in G_2.

B. M-Phase or Mitotic phase or D-phase. It follows the interphase and involves the separation of sister chromatids and their redistribution into daughter cells. It also involves the orderly distribution of cell organelles and macrobiomolecules to the daughter cells. So after M-phase, exactly same hereditary informations are distributed in the daughter cells. It consists of 2 phases: **Karyokinesis** and **Cytokinesis**.

3. Duration of Cell-cycle. It varies from organism to organism and also with cell type. It depends on the type of cell and external factors such as temperature, food and oxygen. Time-period for cell cycle is species specific under specific environmental conditions e.g. 20 minutes for bacterial cell, 90 minutes for yeast cells, 8-10 hours for intestinal epithelial cell, 20 hours for onion root-tip cell, **24 hours for human cells in culture,** 29 hours for *Trillium* etc.

4. Regulation of cells cycle. Stage of regulation of cell cycle is **G_1 phase** during which a cell may follow one of the three options :

(a) It may start a new cell cycle, enter the S-phase and finally divide.

(b) It may be arrested at a specific point of G_1 phase.

(c) It may stop division and enter **G_0 or quiscent stage** so G_0 stage is called as the **state of arrested condition.** But depending upon the requirement of organism, cell in G_0 phase can resume the growth and re-enter the G_1 phase, otherwise it may undergo cell differentiation and specialization. *e.g.* nerve cells, muscle cells, red blood cells and white blood cells. So the cell has an option to stop cell cycle and undergo differentiation.

Once this G_1 check point has been passed and cell entered the S–phase and has begun DNA replication, cell goes on to complete new cell cycle . So **initiation of cell division is triggered by the doubling of DNA in S-Phase (even before the start of M–phase).**

REMEMBER

- Regulation of cell cycle is controlled by a control system formed of certain **check points** where brakes and signal points operate. The **brakes** stop the cell cycle while **feed back signals** initiate the next event of cell cycle only after completion of previous event.
- There are two types of **regulatory proteins** which regulate cell cycle. **Cyclin-Dependent Kinases (cdks)** and **cyclins** which associate to form an activated heterodimeric complex, called **cell cycle engine**.
- Cdks are catalytic subunits of cell cycle engine but are inactive in the absence of cyclin with no catalytic function.
- **First check point** of cell cycle is **G_1 cyclin** which acts as S-phase inhibitor so operates between G_1 and S phases of interphase.
- **Second check point** of cell cycle is **Mitotic cyclin** which operates between G_2 and M phases of interphase.

PRACTICE PROBLEMS – INTERPHASE

1. Define cell reproduction.
2. Name two processes involved in cell cycle.
3. What is interphase?
4. Name three phases of interphase.
5. Give the phase of DNA replication in interphase.

ANSWERS TO PRACTICE PROBLEMS

1. When a fully grown cell divides to produce two daughter cells, it is called **cell reproduction.**
2. Cell growth and cell division.
3. Period between the end of one cell division to the beginning of next cell division is called **interphase.**
4. G_1, S and G_2.
5. S or synthetic phase.

TYPES OF CELL DIVISION

Cell division is of **three types :**
I. Amitosis or **Direct cell division.**
II. Mitosis or **Indirect cell division.**
III. Meiosis or **Reductional division.**

LEARNING PLUS

- Cell division was first studied by **Prevost and Dumas** (1824) when they studied cleavage of zygote of frog.
- **Rudolf Virchow** (1859) : Proposed "*Omnis cellula e cellula*" and **cell lineage theory.**
- Main dividing zones of adults are : **Germ cells** of gonads; **stratum germinativum** of epidermis and **bone marrow** of animals; and **meristems** and **cambial cells** of plants.
- At the molecular level, it is the **DNA** which controls the cell reproduction.
- Some cells of adult animals donot divide at all e.g. heart cells, nerve cells, muscle fibres, etc.
- Some cells divide only when to replace the injured or dead cell.
- DNA replication during cell growth occurs in S-phase of interphase, but DNA polymerase enzyme required for DNA replication is synthesized in G_1- phase of interphase.
- S-phase of interphase is also called **invisible phase**.

I. AMITOSIS (FIG. 2)

(Gr. *amitos* = without thread; *osis* = state)

It is also called **direct or incipient cell division. It is simplest type of cell-division in which there is no synthesis of spindle, no condensation of chromatin fibres and no disappearing of nuclear membrane.**

1. Occurrence. It is found in certain prokaryotes like bacteria and cyanobacteria, yeast and some special eukaryotic cell types e.g. *Amoeba*, **cartilage cells, meganucleus** of *Paramecium*, **foetal membrane cells, endosperm cells of seeds.**

2. Mechanism. It comprises two steps : **(A) Karyokinesis** and (B) **Cytokinesis.**

(a) Karyokinesis. It involves division of nucleus for which nucleus develops a constriction in centre, becomes dumbell-shaped. Constriction deepens and divides nucleus into two.

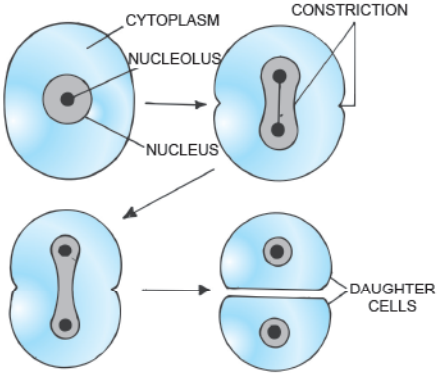


Fig. 2. Stages in Amitosis.

(b) Cytokinesis It involves division of cytoplasm. Plasma membrane develops a constriction along nuclear constriction. It deepens centripetally and finally divides the cell into two cells.

3. Drawbacks. It causes **unequal distribution of chromosomes** leading to abnormalities in metabolism.

II. MITOSIS

It is also called **indirect cell division** or **somatic cell division** or **equational division.** In this, **mature somatic cell divides in such a way that chromosome number is kept constant in daughter cells equal to those in parent cell, so the daughter cells are quantitatively as well as qualitatively similar in genetic material to the parental cell**, so it is called **equational division.**

1. Discovery. It was discovered in plant cells by a German biologist **Strasburger** (1875 A.D.) and in animal cells (in *Triturus* - salamander) by another German biologist **W. Flemming** (1879 A.D.). Term mitosis was given by **Flemming** (1882 A.D.).

2. Time taken. It ranges from 30 minutes to 3 hours. Time is **species-specific** but also depends upon type of tissue, temperature etc. In human somatic cells, cell division lasts for only one hour out of average cell cycle duration of 24 hours.

3. Occurrence. Mitosis occurs both in **somatic cells** (during growth) as well as **germ cells of the gonads** (during multiplicative phase of gametogenesis). In plants, mitosis occurs in the **meristematic cells** (e.g. root apex and shoot apex) and **cambial cells.** In man, it occurs in stratum germinativum of skin, bone marrow, etc. It also occurs during **embryonic development.** Mitosis occurs in both haploid cells (e.g. lower plants and drones of honey bee) and diploid cells (e.g. higher plants and most of animals).

4. Two phases of Mitosis :

A. Karyokinesis or **Nuclear division.**

B. Cytokinesis or **Cytoplasmic division.**

A. Karyokinesis. Though it is a continuous and progressive process but is divided into **four phases** for

convenience on the basis of position and morphology of chromosomes :

(a) Prophase or Spireme stage (Fig. 3). It is the stage of **longest** duration. It is again of **three sub-phases :**

Early Prophase. It is characterized by :

(i) Formation of Asters. It involves :

- Disappearance of centrosphere.
- Development and elongation of proteinous microtubules between two centriole pairs.
- Centriole pairs (diplosomes) start moving towards opposite poles.

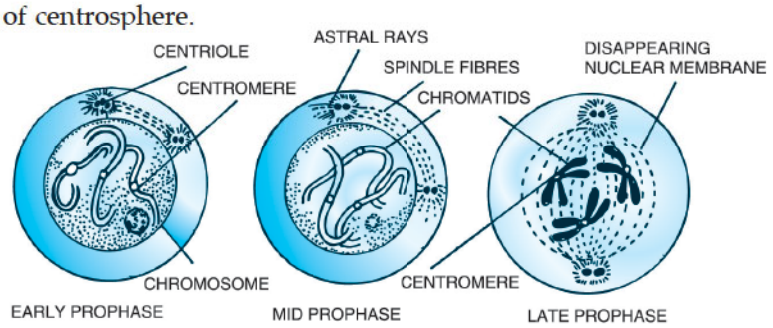


Fig. 3. Prophase of Mitosis.

- Each centriole pair develops fine, radiating protein-microtubules called **astral rays,** forming star-shaped body called **aster.**

(ii) Condensation of Chromatin

Nuclear chromatin condenses into long, thin, thread-like chromosomes by dehydration and spiralization. Each chromosome is formed of **two sister chromatids** joined at or **centromere.** On the surface of each centromere, there are two disc-like areas, called **kinetochores,** and are sites of attachment of spindle fibres **(Fig. 4)**.

Mid Prophase. It is characterized by :

(i) More condensation of chromosomes so that these become shorter, thicker and untangled.

(ii) Further moving away of two asters.

(iii) Nuclear membrane (fragments merge into ER) and nucleolus (sheds its RNA over the chromosomes) start disappearing.

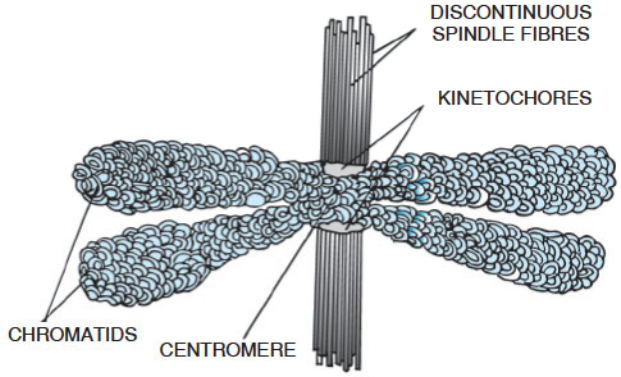


Fig. 4. A metaphase chromosome with two chromosomal fibres attached at the kinetochores.

Late Prophase. It is characterized by :

(i) Nearly complete disappearance of Golgi body, ER, nuclear membrane and nucleolus.

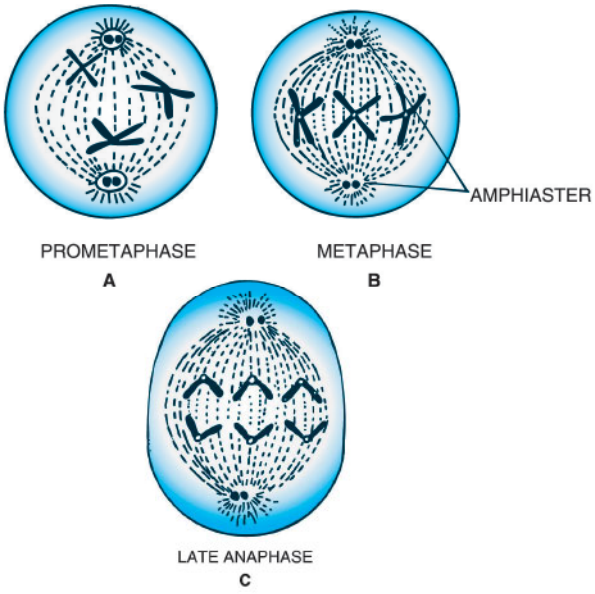


Fig. 5. Prometaphase, Metaphase and Late Anaphase of Mitosis.

(ii) Further condensation of chromosomes.

(iii) Formation of spindle. Two asters become **antipodal** in position and the proteinous microtubules between them take the form of spindle. The central broader part of spindle is called **equator,** while narrow ends of spindle having asters are called **poles.**

(iv) Spindle is formed of two types of spindle fibres :

Chromosomal or **Discontinuous fibres.** These extend from pole to kinetochores of the chromosome.

Continuous or **Interpolar fibres.** These extend from pole to pole.

Both the asters and the spindle are collectively called **mitotic apparatus.**

(b) Metaphase (Fig. 5B). Metaphase chromosomes are maximally condensed so are morphologically most distinct and most easily studied. It takes about **2-10 minutes** and is characterized by:

(i) Chromosomes arrange at equator in **one equatorial** or **metaphase plate**.

(ii) Each centromere is joined by **two chromosomal fibres**, one from each pole.

(iii) Centromeres lie at the equator while arms are directed towards the poles.

Best phase to study the morphology of the chromosomes is **metaphase**.

(c) Anaphase (Figs. 5C and 6). It is of **shortest** duration (only **2-3 minutes)** and is characterized by :

(i) Each centromere splits, so that two sister chromatids have their own centromere and **daughter chromosomes** are formed. Each daughter chromosome is formed of only one chromatid.

(ii) Proteinous **inter-zonal fibres** are developed between centromeres of daughter chromosomes.

(iii) Daughter chromosomes move towards opposite poles and may be V-shaped or J-shaped or rod-shaped. In moving chromosomes, centromeres are towards the pole end hence at leading edge while the arms trail behind.

So anaphase divides the nuclear matter into two equal and similar halves, so called **equational division.**

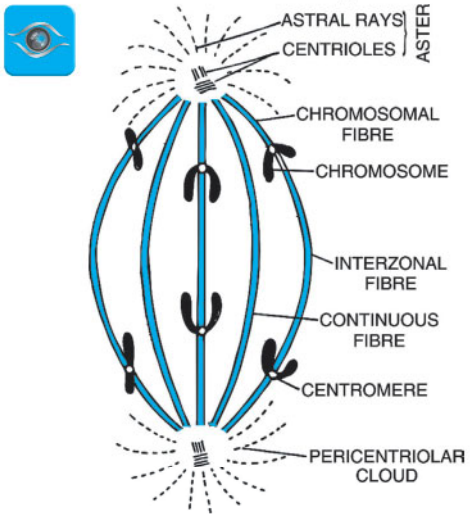


Fig. 6. Anaphase of Mitosis

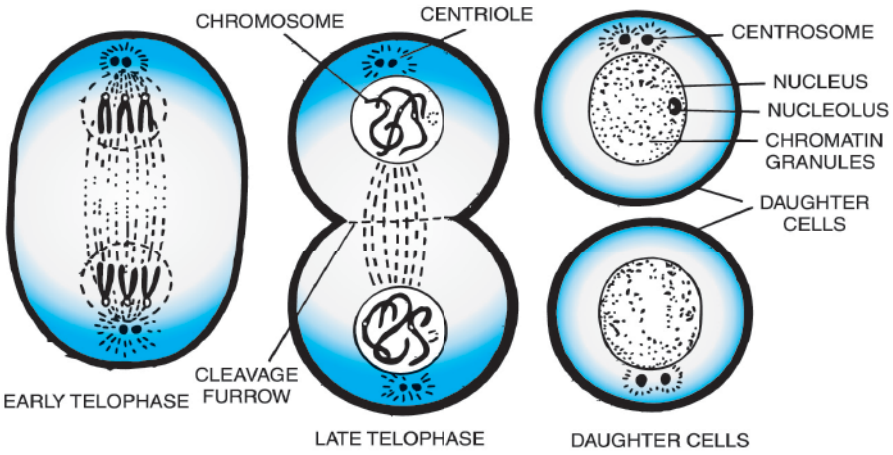


Fig. 7. Telophase of Mitosis.

(d) Telophase (Fig. 7). It takes about **one hour.** It involves the changes which are opposite to prophase :

(i) At each pole, chromosomes are surrounded by a **new nuclear membrane** formed from ER.

(ii) Nucleolus is reformed from **NOR (nucleolar organising region)** of nucleolar chromosome. Golgi body and ER are also reformed.

(iii) Chromosomes decondense by hydration and despiralling to form **nuclear chromatin.**

(iv) Astral and spindle fibres are absorbed in cytoplasm. These **microtubules undergo depolymerisation of tubulin subunits.**

(v) Centrioles, at each pole, are surrounded by centrosphere to complete the centrosome.

B. Cytokinesis (Fig. 8). It involves division of cytoplasm.

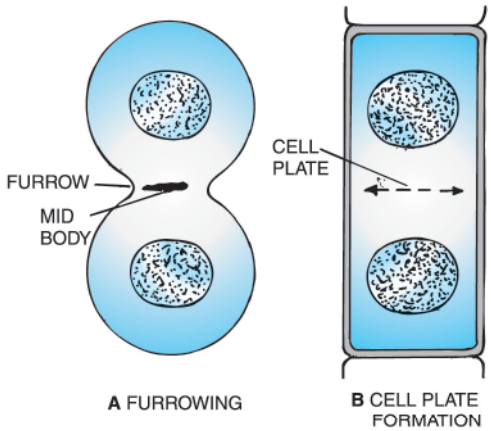


Fig. 8. Cytokinesis.

(a) In animal cells, cytokinesis starts at metaphase during which the cell-organelles like mitochondria arrange themselves equally on either side of equator. During anaphase, a ring of dense material, called

mid-body, is developed at the middle of spindle. Then the cell membrane develops a constriction due to development and contraction of microfilaments which deepens centripetally and is called **cell furrow.** In telophase, cell furrow deepens and finally divides the cell into two daughter cells. It is also found in the pollen-mother cells of some angiosperms. This type of cytokinesis is called **furrowing** or **cleavage.**

(b) In plant cells, cytokinesis occurs by **cell-plate formation,** because these are surrounded by inextensible cell wall (Described in origin of cell wall-Chapter 8).

SIGNIFICANCE OF MITOSIS

(a) It keeps the **Chromosome number constant and genetic stability** in daughter cells, so the **linear heredity** of an organism is maintained.

(b) It helps in **growth and development** of zygote into adult through embryo formation.

(c) It provides new cells for **repair and regeneration** of lost parts e.g. upper layer of epidermis, cells of gut mucosa and blood cells and **healing** of the wounds.

(d) It helps in **asexual reproduction** by fragmentation, budding, stem cutting etc.

(e) Details of mitosis are similar in all living organisms showing **interrelationship** between them.

(f) Keeps a check on cell size.

(f) It also restores the **nucleoplasmic ratio.**

(g) Somatic variations when maintained by vegetative propagation can play **important role in speciation.**

(h) Mitosis keeps a **check on cell size** and maintains a **favourable surface area/volume ratio** which increases the exchanging power of the cell. This is a boy

(i) Mitosis in apical meristems of plants helps in longitudinal growth while mitosis in lateral meristem helps in secondary growth in plants.

Table 1. Differences between cytokinesis in Plant cell and Animal cell.

Character	In Plant cell	In Animal cell
1. **Mechanism**	By **cell plate.**	By **cell furrow.**
2. **Fate of spindle**	Usually persists.	Begins to degenerate.
3. **Mode of formation**	Golgian and ER vesicles called **phragmoplasts** fuse to form cell plate.	A constriction is developed by the contraction of microfilaments in the cell membrane.
4. **Growth**	Cell plate grows centrifugally.	Cell furrow grows centripetally.

COMPETITION PLUS

TYPES OF MITOSIS

1. Anastral mitosis. It is found in **plants** in which spindle has no aster.

2. Amphiastral mitosis. It is found in **animals** in which spindle has two asters, one at each pole.

3. Intranuclear or Promitosis. In this, spindle is formed inside the nuclear membrane e.g. **Protozoans** (*Amoeba*) and **yeast.**

4. Extranuclear or Eumitosis. In this nuclear membrane is lost and spindle is formed outside nuclear membrane e.g. in **plants** and **animals.**

5. Endomitosis. Chromosomes and their DNA duplicate but fail to separate which lead to **polyploidy** e.g. in liver of man, both diploid (2N) and polyploid cells (4N) have been reported. Polytenic chromosomes are also formed by endomitosis.

6. Free nuclear division. In this nucleus undergoes repeated karyokinesis but no cytokinesis occurs. This leads to **coenocytic (multinucleate) condition** in fungal hyphae. It is also found in some fungi (e.g. *Rhizopus*), *Opalina* (a protozoan), endosperm cells of some sea plants and **liquid endosperm in coconut**.

CONTROL OF MITOSIS

- Main factor controlling the cell-division is its **surface-volume ratio.** When a cell increases in size then its surface area increases in squares while its volume increases in cubes. This decreases the surface-volume ratio which in turn leads to decreased exchanging power of the cell. When the critical point in the surface-volume ratio is achieved, cell-division starts. So, **cell division helps in maintaining a favourable surface area to volume ratio.**
- It is also proposed that the **cell-division is initiated due to a change in nucleo-cytoplasmic ratio in the growing cell.** When DNA content is doubled during the S-phase of interphase, then the cell-division is initiated to maintain equilibrium between the **nuclear mass** and **cytoplasmic mass** of the cells called **nucleoplasmic index** (NP) or **karyoplasmic**

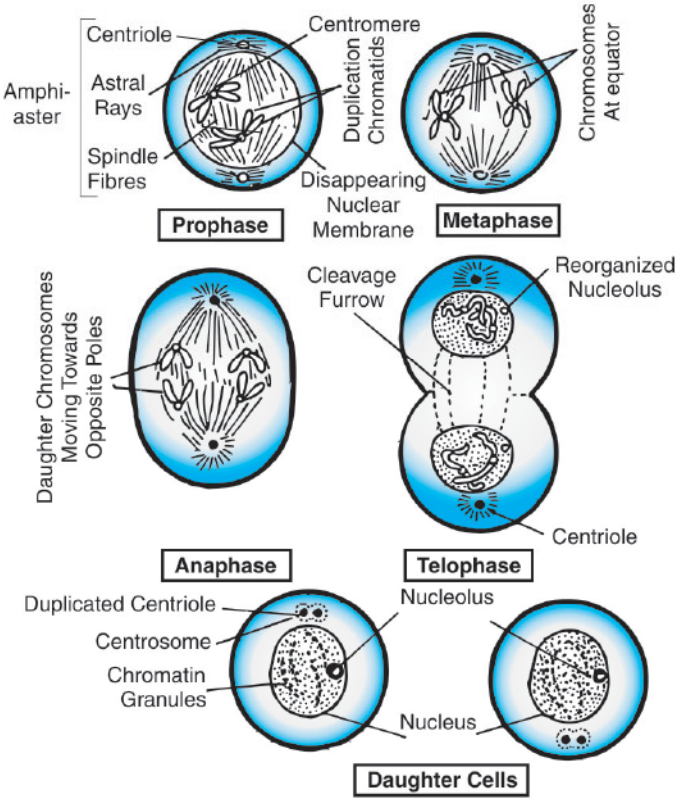


Fig. 9. Mitosis in animal cell.

LEARNING PLUS

- In animals, mitosis occurs only in diploid somatic cells, but the plants show mitosis in both haploid and diploid cells.
- A onion root tip cell having 14 chromosomes will have 14 chromosomes at G_1 phase; 14 chromosomes after S-phase and again 14 chromosomes after M-phase.
- A onion root tip cell having 2C DNA content after M-phase will have 2C DNA in G_1; 4C DNA after S-phase and again 4C DNA at G_2 phase of cell cycle.
- **Robert Ramak** (1855) : Gave the details of amitosis.
- Prophase takes about 71 minutes in onion root tip cells while takes 102 minutes in neuroblasts of grasshopper.
- **Prometaphase :** Phase of short duration between prophase and metaphase in which chromosomes lie irregularly on the spindle.
- During anaphase, telocentric chromosome appears I-shaped, acrocentric and submetacentric chromosomes appears J or L-shaped, while metacentric chromosome appears V-shaped.
- Each spindle fibre is mainly formed of tubulin proteins (95-97%) and some RNA (3-5%).
- In plants, meristematic cells divide throughout life and are located at specific regions e.g. apical meristem at apices of root and stem; and lateral cambium. In animals, such meristems are absent.
- Cell plate formed during cytokinesis of dividing plant cell represents the **middle lamella.**

Table 2. Differences between mitosis in Plant and Animal cells.

Plant cell	Animal cell
1. Centrioles are not present.	1. Centrioles are present.
2. **No aster** formation.	2. **Aster formation** occurs.
3. **Cell plate** is formed.	3. **No cell plate** is formed.
4. **No furrowing** of cytoplasm at cytokinesis.	4. **Furrowing of cytoplasm** at cytokinesis.
5. Occurs mainly in **meristems.**	5. Occurs in tissues **throughout the body.**

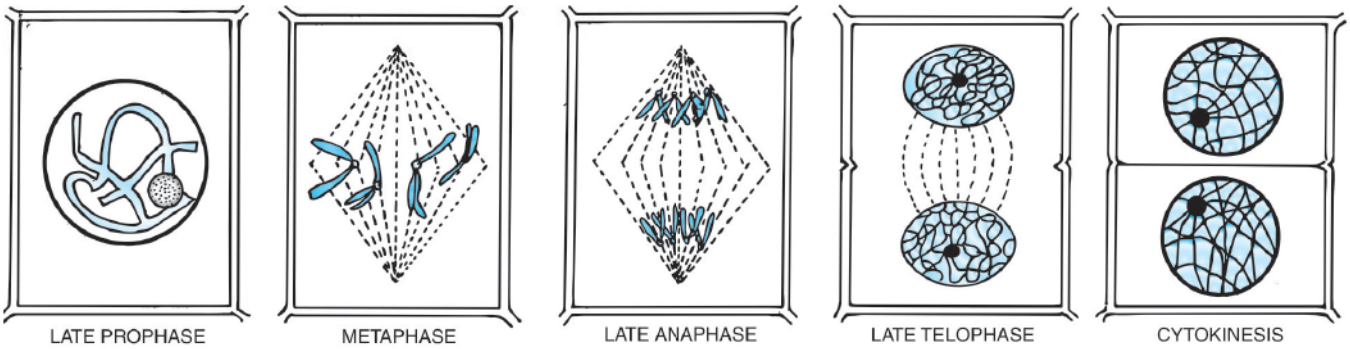


Fig. 10. Mitosis in plant cell.

PRACTICE PROBLEMS – AMITOSIS AND MITOSIS

6. Why is amitosis called incipient cell division?
7. Name two types of cells dividing by amitosis.
8. What is drawback of amitosis?
9. Why is mitosis called equational division?
10. Who gave the term mitosis?
11. Differentiate karyokinesis and cytokinesis.
12. What is kinetochore? What is its function?
13. Name the phase of mitosis of longest and shortest duration.
14. Name two types of spindle fibres.
15. What is peculiar about metaphase of mitosis?
16. What is peculiar about anaphase of mitosis?
17. Give one significance of mitosis.
18. How does spindle of a dividing animal cell differ from that of plant cell?
19. How does the cytokinesis of dividing plant cell and animal cell differ from each other?
20. Give the main factor regulating the mitosis.

ANSWERS TO PRACTICE PROBLEMS

6. As it is simplest type of cell division in which there is no condensation of chromatin fibres and no formation of spindle.
7. Cartilage cells and meganucleus of *Paramecium*.
8. Causes unequal distribution of chromosomes.
9. It keeps the chromosome number constant.
10. W. Flemming.
11. Karyokinesis involves nuclear division while cytokinesis involves division of cytoplasm.
12. Kinetochore is a discoidal area on a chromatid. It is site of attachment of chromosomal fibre of spindle.
13. Prophase is of longest duration while Anaphase is of shortest duration.
14. Chromosomal fibres and continuous fibres.
15. Chromosomes are arranged in one equatorial plate at the equator of spindle.
16. Chromatids (daughter chromosomes) more towards opposite poles of spindle.
17. It provides new cells to help in growth and repair of body tissues.
18. Spindle is **amphiastral** (with two asters) in animal cell but is **anastral** (no aster) in plant cell.
19. Cytokinesis occurs by **cell furrow** in animal cell but by **cell plate** in plant cell.
20. Increase in DNA amount by DNA replication in S-phase.

ADDITIONAL USEFUL INFORMATIONS ABOUT CELL CYCLE, AMITOSIS AND MITOSIS FOR COMPETITIVE EXAMINATIONS

- ***Scientists associated with cell cycle and mitosis :***
  - ***Howard and Pelc*** (1953): Gave details of cell cycle.
  - ***Schneider (1887):*** Coined the term karyokinesis.
  - ***Whitemann (1887):*** Coined the term cytokinesis.
- Interphase nucleus is with long and thread like chromatin fibres (not condensed chromosomes) for error-free replication of DNA.
- Period for sub-phases of cell cycle is : G_1 = 42%; S = 33%; G_2 = 21% and M = 4-10%.
- ***Generation time : Period between the successive divisions.***
- MITOSIS :
  - ***Time taken in different phases of karyokinesis :***
    - *Prophase = **2-3%** of total time. It is of **longest** period.*
    - *Metaphase = About **1%** of total time.*
    - *Anaphase = Less than **0.5%** of total time. It is of **shortest** period.*
    - *Telophase = About **1-1.5%** of total time.*
  - ***Plectonemic coiling :*** *When sister chromatids are tightly coiled upon each other. It is found during mitosis.*
  - ***Spireme stage :*** *Thread-like chromosomes form a mass like a ball of wool during early prophase of mitosis.*
  - ***Amphiastral spindle**: Also called **bipolar spindle :** When spindle is with an aster at each pole. It is formed in dividing animal cells.*
  - ***Anastral spindle*** *Spindle has no aster. It is formed during cell division in plant cells.*
  - *Formation of astral and spindle fibres during prophase involves **polymerization** of the microtubules, while their dissolution during telophase involves **depolymerization** of the microtubules.*
  - *In animal cells, cytokinesis occurs **centripetally**, while in plant cells, cytokinesis occurs **centrifugally.***
  - *Mitosis occurs in both diploid and haploid cells.*
  - *Mitosis ensures **genetic homogeneity.***
  - *Mitosis is best studied in onion root tip cells in which chromosomes are stained with **acetocarmine** (a basic fuchsin stain).*

- *Mitogens : The agents which stimulate cell division e.g. cytokinins, auxins, gibberllins, insulin, temperature, steroids, etc.*
- *Mitotic poison : The agents which inhibit cell division.*
  - *— Azides and cyanides inhibit prophase.*
  - *— Colchicine inhibits spindle formation at metaphase.*
  - *— Mustard gas agglutinates the chromosomes.*
  - *— Carbon monoxide inhibits Krebs cycle so inhibits cell division.*
- *Endosperm of gymnosperms is haploid, root cells are diploids while endosperm of angiosperms is triploids.*
- *Dinomitosis : Mitosis in dinoflagellates in which nucleolus and nuclear membrane persist during mitosis.*
- *Mesokaryon : Nucleus with condensed chromosomes even in interphase e.g. in dinoflagellates.*
- *Mitotic apparatus is formed of spindle microtubules, microtubule-associated proteins (MAPs) and asters. Spindle microtubules are of three types: astral, interpolar and kinetochoral microtubules. MAPs include γ-proteins, kinesins and dynein proteins.*

III. MEIOSIS (Gr. *meioum* = to reduce; *osis* = state—FIGS. 13—14)

1. Definition. It is a special type of division in which the **chromosomes (or DNA) duplicate only once, but cell divides twice. So one parental cell produces 4 daughter cells; each having half the chromosome number and DNA amount than normal parental cell.** So meiosis is also called **reductional division.**

2. Occurrence. It is found in special cell types and at specific period. It is reported in diploid **germ cells** of sex organs (e.g. **primary spermatocytes of testes** to form **spermatozoa** and **primary oocytes of ovaries** to form **ova** in animals) and in **pollen mother cells (microsporocytes)** of anther and **megasporocyte of ovule** of ovary of flowers in plant to form the haploid **spores.**

3. Discovery. It was first demonstrated by **Van Benden** (1883 A.D.) but was described by **Winiwarter** (1900 A.D.). Term "**meiosis**" was given by **Farmer and Moore** (1905 A.D.) from Greek word *meioum* = to reduce.

4. Mechanism. Meiosis comprises **two divisions : Meiosis-I** and **Meiosis-II**

MEIOSIS-I (FIG. 13)

It is also called **reductional division** or **heterotypical division** because it involves the formation of two daughter cells which have chromosome number half to those in the parental cell. It is initiated only after replication of chromosomes and DNA during S-phase of interphase.

It is divided into **two parts : A. Karyokinesis-I** and **B. Cytokinesis-I.**

A. Karyokinesis - I. It involves division of nucleus. It is divided into **four phases :**

1. Prophase-I. It is of **longest duration** and even longer and more complex than that of mitosis (about 100 to 200 times). It is again divisible into **five subphases on the basis of chromosome behaviour.**

(a) Leptotene or **Leptonema**. It is also called **thin-threaded stage.** It involves :

(i) Volume of nucleus increases.

(ii) Formation of **aster** (as in mitosis).

(iii) Condensation of nuclear chromatin by dehydration and spiralization into species-specific number of **chromosomes.** Each chromosome is formed of two sister chromatids but still appears single and long thread-like. Each has a linear series of darkly stained beads called **chromomeres.**

(b) Zygotene or Zygonema It is also called **yoked-threaded stage.** It involves :

(i) Pairing (called **Synapsis** or **Syndesis**) of homologous chromosomes to form **bivalents** so each bivalent is formed of four chromatids and two centromeres.

(ii) Number of bivalents is half to total number of chromosomes in a diploid cell. Each bivalent is formed of one paternal and one maternal chromosome.

(iii) Further condensation of chromosomes and moving away of asters.

(iv) Under EM, a filamentous ladder-like nucleoproteinous complex, called **synaptonemal complex (Fig. 11),** is observed between the homologous chromosomes. It forms structural basis for pairing and synapsis of meiotic chromosomes.

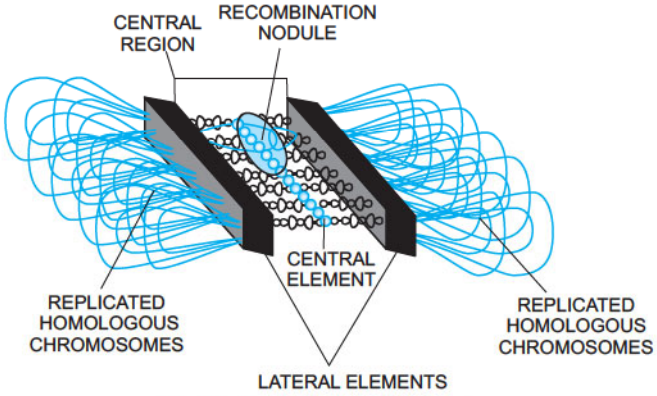


Fig. 11. Synaptonemal complex.

(c) Pachytene or **Pachynema**. It is also called **thick-threaded stage.** It involves :

(i) Further condensation of chromosomes. Each chromosome is now visibly formed of two **sister-chromatids** joined at centromere and is called a **dyad.** Each bivalent has two dyads and is called a **tetrad**

(ii) Sometimes **exchange of genes** or **crossing over (Fig. 12) between two non-sister chromatids of homologous chromosomes occurs** at the x-shaped points called **recombination nodules** which appear on the synaptonemal complex. It is an enzymatically–controlled process and is regulated by **recombinase enzyme.**

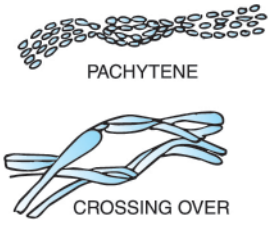


Fig. 12. Crossing over.

(iii) Moving away of asters.

(d) Diplotene or **Diplonema** or **Double threaded stage.** It is of **longest duration** and involves :

(i) Nuclear membrane and nucleoli start disappearing.

(ii) Desynapsis of homologous chromosomes begins due to dissolution of synaptonemal complex. The separation is however not completed and they remain attached at one or more X–shaped points, called **chiasmata,** where crossing over has occurred. Number of chiasmata depends upon the length of chromosome. The chiasmata start moving towards the ends of chromosomes, called **terminalisation.**

(e) Diakinesis. It involves :

(i) Terminalisation is completed so the non-sister chromatids are in contact with each other at or near their telomeres, so the bivalents appear ring-like.

(ii) Complete disappearance of nuclear membrane and nucleoli.

(iii) Formation of spindle (as in mitosis).

2. Metaphase-I. It involves :

(a) Bivalents arrange in two parallel **equatorial or metaphase plates.** Each plate has one genome.

(b) Centromeres of homologous chromosomes lie **equidistant** from equator and are directed towards the poles while arms generally lie horizontally on the equator.

(c) Each homologous chromosome has two kinetochores which are joined to the **chromosomal** or **tractile fibre** of same side.

(d) Proteinous **inter-zonal fibres** develop between centromeres of homologous chromosomes.

3. Anaphase-I. It involves **separation of homologous chromosomes** which start moving towards opposite poles so each tetrad is divided in two dyads. **So Anaphase-I involves the reduction of chromosome number decides the genetic constitution of the cells to be formed (i.e., gametes).** The shape of separating chromosomes may be rod or J or V-shape depending upon the position of centromere.

4. Telophase-I. It may or may not occur. When it occurs, its changes are **opposite to those of Prophase-I:**

(a) At each pole, a **daughter nucleus** with nuclear membrane (from ER) and nucleolus is formed.

(b) Disappearance of astral rays and spindle fibres.

(c) Completion of centrosome.

(d) Chromosomes undergo decondensation by hydration and despiralization and change into long and thread-like chromatin fibres.

B. Cytokinesis-I. It may or may not be present. When present, it occurs by **cell-furrow** formation in animal cells and **cell plate** formation in plant cells. The nucleus of each daughter cell has half the number of chromosomes than the parental cell.

Significance of Meiosis-I

1. It involves **disjunction** and reduces the chromosome number.

2. Chromosomal and **genomic mutations** may occur due to non-disjunction.

3. Recombinations of genes and so **variations** are produced due to **crossing-over** during late pachytene and **chance orientation of bivalents** at the equator.

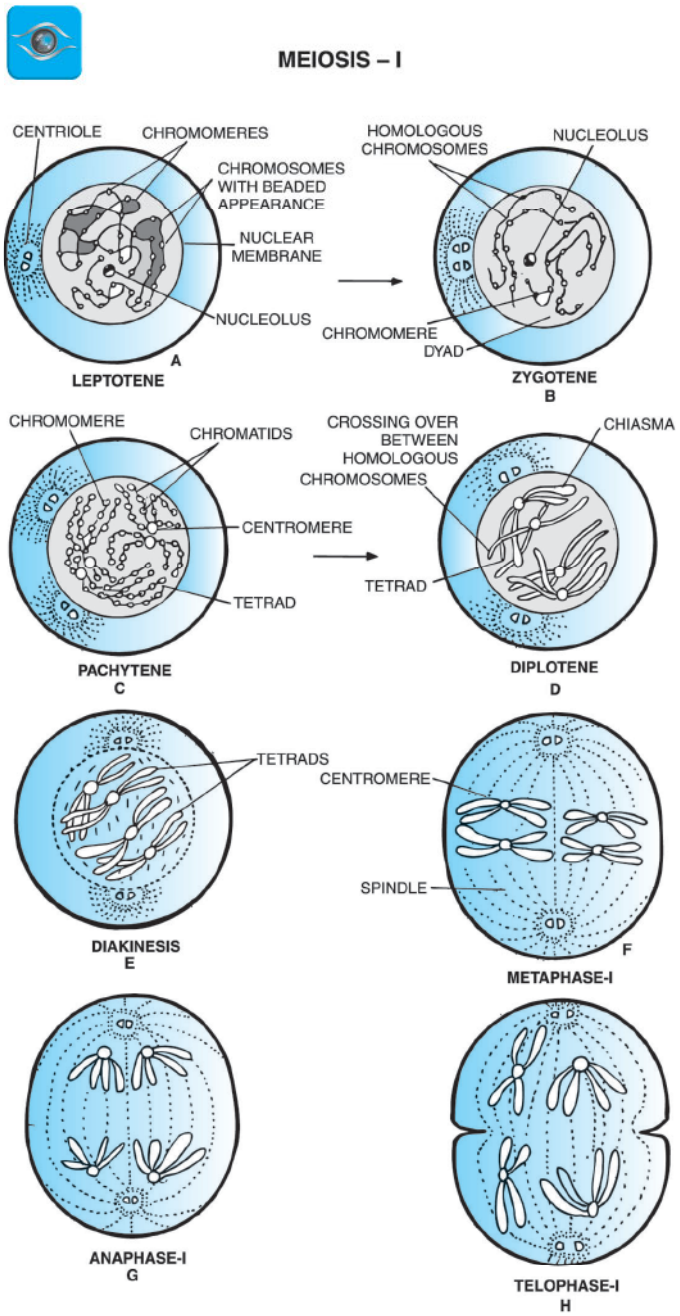


Fig. 13. Stages of Meiosis-I.

Interkinesis or intrameiotic interphase. It is the period between telophase of meiosis-I and prophase of meiosis -II. It may or may not be present. When

present, it involves only protein and RNA synthesis but there is **no S-phase and no DNA synthesis.** It involves the duplication of centrioles and formation of spindle proteinous fibres to form two new spindles.

MEIOSIS-II (FIG. 14)

It is also called **equational** or **homotypical division** because the number of chromosomes remains same as after meiosis-I. It is of shorter duration than even typical mitotic division. It is also divisible into **two parts**: **A. Karyokinesis-II** and **B. Cytokinesis-II**.

A. Karyokinesis-II. It involves the separation of two chromatids of each chromosome and their movement to separate cells. It is divided in **four phases:**

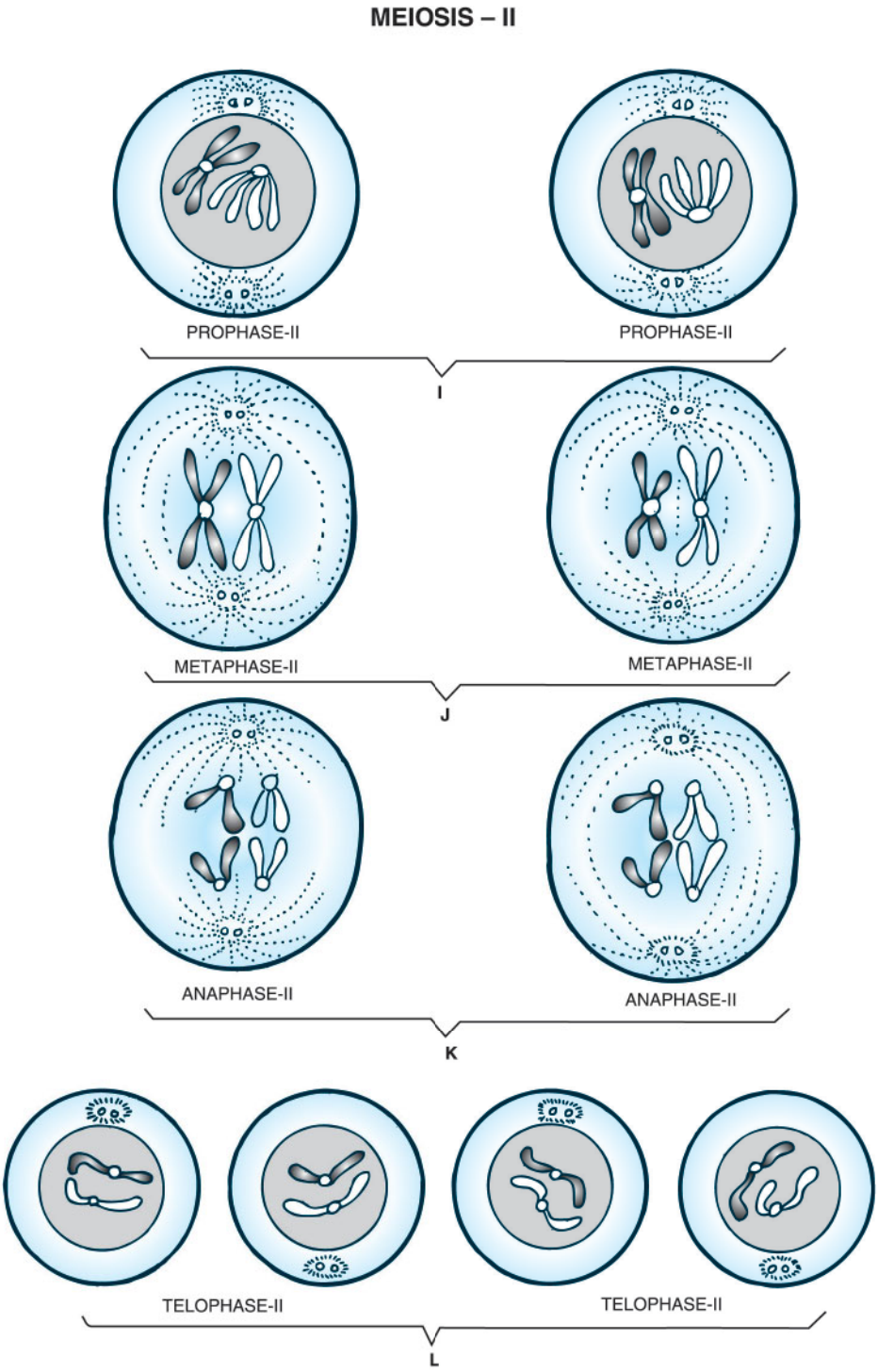


Fig. 14. Stages of Meiosis-II.

Table 3. Differences between Mitosis and Meiosis-II.

Characters	Mitosis	Meiosis-II
1. Occurrence	Occurs in both diploid and haploid cells.	Occurs only in haploid cells produced by meiosis-I.
2. Followed by	Interphase.	Not followed by interphase.
3. Nature of separating chromatids	Genetically similar.	May be genetically similar or dissimilar.

1. Prophase-II. It involves :

(a) Formation of **asters** from the centrioles.

(b) Disappearance of **nuclear membrane and nucleolus.**

(c) Condensation of chromatin fibres into definite number of chromosomes.

(d) Formation of achromatic bipolar spindle. Each chromosome is formed of two sister chromatids joined at the centromere. **Spindle of prophase-II is perpendicular to that of prophase-I.**

2. Metaphase-II. It involves :

(a) Arrangement of chromosomes in **one equatorial plate.**

(b) Each centromere is joined by two **chromosomal fibres.** Two chromosomal fibres join at the kinetochores.

3. Anaphase-II. It involves :

(a) Splitting of centromere of each chromosome and formation of **two daughter** or **new chromosomes.**

(b) Development of **inter-zonal fibres**.

(c) Movement of daughter chromosomes.

4. Telophase-II. It is always present and involves changes opposite to those of prophase-II:

(a) Formation of daughter nucleus at each pole due to appearance of nuclear membrane (from ER), nucleoli.

(b) Disappearance of astral rays and spindle fibres.

B. Cytokinesis-II. It is always present and occurs by **cell furrow** formation in animal cell and **cell plate** formation in plant cell.

Need of Meiosis-II

Disjunction is the peculiar feature of anaphase-I and involves the separation of homologous chromosomes into different daughter cells. So Meiosis-I is called **reductional division.** But each chromosome is still a **dyad** *i.e.* formed of two sister chromatids joined at the common centromere. So though the chromosome number has been halved, but each chromosome still has double (2N) amount of DNA. So there is need of Meiosis-II during which sister chromatids of each chromosome separate into different cells, **haploidy occurs even in DNA amount.** Main aim to Meiosis -II is to separate genetically modified chromatids formed during crossing over in Meiosis-I.

KEY FEATURES OF MEIOSIS

- Meiosis involves two sequential cell divisions but involves only a single cycle of DNA replication.
- Prophase-I is formed of five subphases: Leptotene, zygotene, pachytene, diplotene and diakinesis.
- Zygotene of prophase-I involves pairing of homologous chromosomes.
- Pachytene of Prophase-I involves crossing over and recombination of genes.
- Pairing and recombination between homologous chromosomes is unique feature of Prophase-I of meiosis.
- At the end of meiosis, diploid parental cell produces four haploid gametes.

SIGNIFICANCE OF MEIOSIS

1. It produces **haploid gametes** or **spores** so **meiosis is antithesis to fertilization**.

2. Meiosis and fertilization both work in coordination to maintain **constant chromosome number** generation after generation. It is so because sexual reproduction without meiosis will result in **tetraploidy** while sexual reproduction without fertilization will lead to **haploidy.**

Table 4. Differences between Mitosis and Meiosis.

Characters	Mitosis	Meiosis
	I. GENERAL	
1. **Site of occurrence**	**Somatic cells** and during the multiplicative phase of gametogenesis in germ cells.	**Reproductive or Germ cells** of gonads.
2. **Period of occurrence**	Throughout life.	During sexual reproduction.
3. **Nature of cells**	**Haploid** or **diploid.**	Always **diploid.**
4. **Number of divisions**	Parental cell divides **once.**	Parent cell divides **twice.**

5. **Number of daughter cells**	**Two.**	**Four.**
6. **Nature of daughter cells**	**Genetically similar** to parental cell. Amount of DNA and chromosome number is same as in parental cell.	**Genetically different** from parental cell. Amount of DNA and chromosome number is half to that of parent cell.
	II. PROPHASE	
7. **Duration**	Shorter (of a few hours) and simple.	Prophase-I is very long (may be in days or months or years) and complex.
8. **Subphases**	Formed of **3 subphases :** early-prophase, mid-prophase and late-prophase.	Prophase-I is formed of **5 sub-phases**—Leptotene, Zygotene, Pachytene, Diplotene and Diakinesis.
9. **Bouquet stage**	Absent.	Present in **Leptotene** stage.
10. **Synapsis**	Absent	Pairing of homologous chromo-somes in **Zygotene** stage.
11. **Chiasma formation and crossing over**	Absent.	Occurs during **Pachytene** stage of Prophase-I.
12. **Disappearance of nucleolus and nuclear membrane**	Comparatively in earlier part.	Comparatively in later part of Prophase-I.
13. **Nature of coiling**	**Plectonemic**	**Paranemic**
	III. METAPHASE	
14. **Metaphase plates**	**Only one** equatorial plate.	**Two plates** in Metaphase-I but one plate in Metaphase-II
15. **Position of centromeres** generally directed towards	Lie **at the equator.** Arms are poles in Metaphase-I while lie at the poles.	**Lie equidistant** from equator and towards the equator in Metaphase-II.
16. **Number of chromosomal fibres**	**Two chromosomal fibres** join at centromere.	**Single** in Metaphase-I while two in Metaphase-II.
	IV. ANAPHASE	
17. **Nature of separating chromosomes**	**Daughter chromosomes** (Chromatids with independent centromeres) separate.	**Homologous chromosomes** separate in Anaphase-I while chromatids separate in Anaphase-II.
18. **Splitting of centromeres and development of inter-zonal fibres**	Occurs in **Anaphase.**	No splitting of centromeres. Inter-zonal fibres are developed in Metaphase-I.
	V. TELOPHASE	
19. Occurrence	Always occurs.	Telophase-I may be absent but Telophase-II is always present.
	VI. CYTOKINESIS	
20. **Occurrence**	Always occurs. Cytokinesis-II is always present.	Cytokinesis-I may be absent but
21. **Nature of daughter cells**	2N amount of DNA than 4N amount of DNA in parental cell.	1N amount of DNA than 4N amount of DNA in parental cell.
22. **Fate of daughter cells**	Divide again after interphase.	Do not divide and act as gametes.
	VII. SIGNIFICANCE	
23. **Functions**	Helps in growth, healing, repair and multiplication of somatic cells.	Produces **gametes** which help in sexual reproduction.
	Occurs in both asexually and sexually reproducing organisms.	Occurs in only sexually reproducing organisms.
24. **Variations** as it keeps quality and quantity of genes same.	**Variations are not produced** chance arrangement of bivalents at Metaphase-I.	**Produces variations** due to crossing-over and
25. **In evolution**	**No role** in evolution.	It plays an important role in **speciation and evolution.**

3. Meiosis produces **new combination of genes** due to **crossing over** and **chance arrangement of bivalents at equator,** producing **genetic variability** which helps in evolution and improvement of the races.

4. It proves **inter-relationship** between living organisms because its details are basically similar.

5. It also causes **multiplication,** as in Meiosis each diploid parental cell produces four haploid cells.

6. Chromosomal and genomic mutations caused by non-disjunction etc. are sources of **useful variations**.

R U CURIOUS

- The four haploid cells formed by meiosis may or may not be equal in size.
- Synapsis may be **Proterminal** (extends from ends towards centromere); **Procentric** (extends from centromere towards ends of chromosomes); or **Random** (starts at any intercalary point).
- Most accepted theory of crossing over is **Breakage and reunion hypothesis** proposed by **Darlington**.
- **Diplotene** lasts for months or years in oocytes of some vertebrates.
- **Colchicine :** An alkaloid extracted from the corm of Autumn Crocus (*Colchicum autumnale*). It acts as **mitotic poison** as breaks the microtubules of spindle and arrests the cell division at metaphase. It is employed to induce **polyploidy** in the plants.
- **Cancer :** Characterized by uncontrolled growth and cell division which leads to **tumour** formation.

LEARNING PLUS

TYPES OF MEIOSIS (FIG. 15)

On the **basis of period and site of occurrence,** meiosis is of **three types :**

A. Gametic or Terminal Meiosis.

B. Zygotic or Initial Meiosis.

C. Sporogenetic or Intermediate Meiosis

A. Gametic Meiosis. It is characterized by :

1. Diploid individual forms **haploid gametes by meiosis** during gametogenesis in the gonads.

2. Haploid gametes fuse to form **diploid zygote** which by mitosis forms diploid adult.

3. Life cycle is **diplontic.**

e.g. **Animals except protozoans.**

B. Zygotic Meiosis. It is characterized by :

1. Haploid individual forms **haploid gametes by mitosis.**

2. Haploid gametes fuse and form **diploid zygote** which **undergoes meiosis** followed by mitotic division to form haploid adult.

3. Life cycle is **haplontic.**

e.g. **Algae, Fungi, Bryophytes and Protozoans.**

C. Sporogenetic Meiosis. It is characterized by :

1. Diploid **spore mother cells** of sporophytic plant undergo meiosis to form the haploid **spores**.

2. Haploid spore germinates to form **haploid gametophyte** which produces the **haploid gametes** by mitosis.

3. Haploid gametes fuse to form **diploid zygote** which develops into diploid sporophyte by mitosis.

e.g. In higher plants like **Pteridophytes, Gymnosperms** and **Angiosperms.**

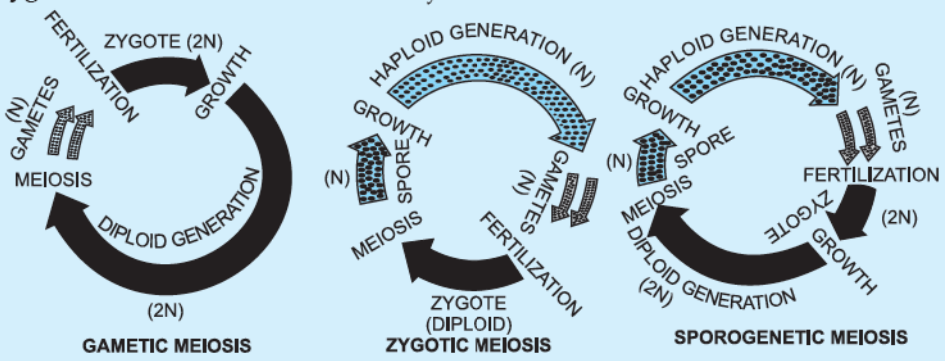


Fig. 15. Three types of Meiosis.

PRACTICE PROBLEMS – MEIOSIS

21. What is nature of daughter cells produced by meiosis?
22. Who gave the term meiosis?
23. Give the site of occurrence of meiosis.
24. Define synapsis. List the phase of its occurrence.
25. Define crossing over. What is its significance?
26. What is peculiar about Metaphase-I of meiosis?
27. Define disjunction.
28. What is interkinesis?
29. Why is Meiosis-I called heterotypical division?
30. Give one significance of meiosis.

ANSWERS TO PRACTICE PROBLEMS

21. Daughter cells are haploid and have half the chromosome number than that in the parental cell.
22. Farmer and Moore (1905).
23. Germ cells of testes and ovaries of animals, pollen mother cells and ovules of plants.
24. Synapsis is pairing of homologous chromosomes and occurs in zygotene.
25. Crossing over is exchange of genetic material between non-sister chromatids of homologous chromosomes. It produces new combination of genes and so produces variations.
26. Bivalents are arranged at the equator of spindle in two plates.
27. Separation of homologous chromosomes in Anaphase-I of meiosis.
28. Interphase between Meiosis-I and Meiosis-II .
29. As the cells produced after Meiosis-I are different from the parental cell and have half the chromosome number than in parental cell.
30. Produces gametes for fertilization and variations due to new combination of genes.

ADDITIONAL USEFUL INFORMATIONS ABOUT MEIOSIS FOR COMPETITIVE EXAMINATIONS

- ***Meiocytes :*** *Cells undergoing meiosis.*
- *Materials commonly used to study meiosis are: unopened floral buds of* ***Tradescantia*** *and testes of grasshopper.*
- ***Paranemic coiling :*** *When sister chromatids are loosely arranged and are easily separable. It is found in meiotic chromosomes.*
- ***Bouquet stage :*** *Polarized orientation of chromosomes during leptotene stage in meiotic animal cells. In this, the ends of chromosomes are attached to the nuclear membrane at an* ***attachment site.***
- *Synapsis was first reported by* ***Montegomery*** *(1901). It occurs in zipper-fashion between the homologous chromosomes.*
- ***Synaptonemal complex :*** *It was first reported by* ***M. J. Moses*** *(1956) in the spermatogenesis is cray fish and stabilizes the paired condition of meiotic chromosomes. It extends from zygotene to pachytene.*
- ***Feulgen stain*** *is specific for DNA.*
- ***Chiasmata :*** *First reported by* ***Janssens*** *(1909). The chiasmata mark the sites of crossing over.*
- ***Darlington*** *(1937) : Proposed* ***breakage and reunion hypothesis*** *of crossing over. Breaking of non-sister chromatids is caused by* ***endonuclease enzyme*** *or* ***U-protein*** *(called* ***nicking****), while reunion of the broken segments to non-sister chromatids is controlled by* ***ligase enzyme*** *or* ***R-protein*** *(called* ***re-annealing****).*
- *Diplotene is the* ***longest and most active subphase*** *of prophase-I of meiosis.*
- ***Disjunction****: Normal separation of homologous chromosomes during Anaphase-I. It corresponds to* ***Mendel's law of segregation.***
- *Independent arrangement of the bivalents supports the law of independent assortment of Mendel*
- ***Non-disjunction :*** *Failure of separation of homologous chromosomes in meiosis. It way first reported by* ***Bridges****.*
- ***Brachymeiosis :*** *Failure of meiosis-II. It is characteristic feature of fungi.*
- *Number of meiosis required to produce zygotes or seeds or fruit :* ***Number required × 1.25***
  It is so as one meiosis produces one ovum but 4 pollens in most of cases.
- *In* ***Cyperus****, one meiosis produces only one pollen instead of four so total meiotic divisions required to produce fruits will be =* ***number of fruits × 2.***
- *Meiosis involves both* ***haploidization and crossing over.***
- *Cytokinesis of meiosis is of 2 types:*
  - ***Successive type:*** *Cytokinesis occurs after each karyokinesis e.g. in monocots.*
  - ***Simultaneous type****: When cytokinesis-I is absent and both cytokinetic divisions occur after karyokinesis-I e.g. in* ***dicots****.*

CHAPTER SUMMARY

- Cell division not only helps in growth and development, repair and regeneration but also helps in continuity of life through cell reproduction. So cell division is essential for perpetuation of species.
- Cell reproduction involves cell growth and cell division. Sum of all the changes which occur during cell growth and cell division is called **cell cycle**.
- Cell cycle is formed of 2 parts : **Interphase** and **M-phase**. Interphase forms about 95% of cell cycle and prepares the cell for cell division. Interphase is formed of 3 subphases : G_1 phase (phase of pooling of amino acids and nucleotides, synthesis of proteins and RNA synthesis, etc.); **S-phase** (phase of DNA replication and synthesis of histones) and **G_2-phase** (phase of synthesis of spindle proteins and duplication of mitochondria, plastids and centrioles).
- **M-or mitotic phase** involves karyokinesis and cytokinesis.
- Duration of cell-cycle varies in different organisms as well as different cell types of same organism.It is of 24 hours for human cells in culture medium.

- **Stage of regulation** of cell cycle is G_1 phase from where the cell may enter S-phase or arrested in G-phase or enter G_0**-phase** (quiescent phase with state of arrested condition). Initiation of M-phase is triggered by doubling of DNA in S-phase of interphase.
- Cell division is of 3 types: **Amitosis**, **Mitosis** and **Meiosis**. Amitosis is characterized by absence of spindle and does not involve condensation of chromatin fibres and disappearance of nuclear membrane. It is found in *Amoeba*, **Cartilage cells**, endosperm cells of seeds, etc.
- **Mitosis** keeps chromosome number constant so is also called **equational division**. It occurs in somatic cells (e.g. meristematic cells of plants and lowermost layer of skin) as well as germ cells of gonads. It is formed of 2 phases: **karyokinesis** (nuclear division) and **cytokinesis**. Karyokinesis is formed of 4 phases: Prophase, Metaphase, Anaphase and Telophase. **Prophase** is characterized by aster formation, spindle formation, condensation of chromatin fibres into chromosomes, and disappearance of nuclear membrane and nucleolus. **Metaphase** is characterized by arrangement of chromosome in one equatorial plate. **Anaphase** is characterized by splitting of each chromosome into two sister chromatids and their movement towards opposite poles. **Telophase** is characterized by organization of true nucleus at each pole and disappearance of spindle and astral fibres. **Cytokinesis** is characterized by division of cytoplasm and occurs by **cell plate** formation in plant cells and **cell-furrow** formation in animal cells.
- **Mitosis helps** in genetic stability, growth and development, repair and regeneration, healing of wounds, asexual reproduction, etc.
- Mitosis is **anastral** (with no aster) in plant cells, while it is **amphiastral** in animal cells.
- **Meiosis** is a special type of cell division in which one parental cell divides twice to produce 4 daughter cells in such a way that chromosome number and amount of DNA is halved; so is also called **reductional division**. It occurs only in diploid germ cells of plants and animals and produce haploid gametes.
- Meiosis is formed of two cell divisions: **Meiosis-I** and **Meiosis-II** with no interkinesis or of short period in which no DNA replication occurs. Meiosis-I is divided into karyokinesis-I and cytokinesis-I.
- Karyokinesis-I is divided into four subphases: Prophase-I, Metapahse-I, Anaphase-I and Telophase-I. Prophase-I is again divided into 5 subphases: **Leptotene** (involves formation of aster and condensation of nuclear chromatin begin); **Zygotene** (involves synapsis and formation of synaptinemal complex); **Pachytene** (involes tetrad formation, chiasma formation and crossing over); **Diplotene** (involves desynapsis, terminalisation, disappearance of nuclear membrane and nucleoli and formation of spindle) and **Diakinesis** (involves completion of terminalization). **Metaphase-I** is characterized by **arrangement of bivalents** (paired homologous chromosomes) in two equatorial plates. **Anaphase-I** is characterised by moving of homologous chromosomes towards opposite poles so causes reduction in chromosome number). **Telophase-I** involves reorganisation of daughter nucleus at each pole.
- **Cytokinesis-I** may or may not occur. **Interkinesis**, when present, involves only protein and RNA synthesis but no S-phase and DNA replication.
- **Meiosis-II** is like Mitosis and involves separation of genetically modified sister chromatids so brings haploidy in DNA amount while meiosis-I brings reduction in chromosome number only.
- **Meiosis** is of 3 types: **Gametic meiosis**, **zygotic meiosis** and **sporogenetic meiosis**.
- Meiosis is significant that it forms **haploid gametes** and produces new combination of genes due to crossing over and random arrangement of bivalents at equator during metaphase-I so produces **variations** which help in **evolution**.

KEY TERMS

Amphiastral spindle	:	A spindle with an aster at each pole. Found during cell division in animals.
Anastral spindle	:	Spindle with no aster. Found in plant cell division.
Aster	:	The astral rays with a centriole is referred to as aster.
Cell-cycle	:	Sum of all those changes which occur during cell growth and cell-division.
Centromere	:	A specific region where two chromatids remain joined along their length; the region of chromosome with no gene.
Chiasma	:	X-shaped point formed due to crossing of two non-sister chromatids.
Cytokinesis	:	Division of cytoplasm.
Disjunction	:	Separation of homologous chromosomes during anaphase-I.
Endomitosis	:	Type of mitosis in which chromosomes duplicate but fail to separate leading to polyploidy.
Interphase	:	An active phase of growth and synthetic activity in the cell consisting of G_1, S, G_2 substages.
Karyokinesis	:	Division of nucleus during cell division.
Meiosis	:	Reductional division which involves the formation of haploid gametes from diploid germ cells in the gonads.
Mitotic spindle	:	Microtubules forming a bipolar fibrous structure during prophase and a component of mitotic apparatus.
Synapsis	:	Pairing of homologous chromosomes during meiosis.
Terminalisation	:	Movement of chiasma towards the ends of the chromosomes.
Tetrad	:	A group of four chromatids of two homologous chromosomes.

NCERT FILE Solved

NCERT Exercise Questions

1. What is average cell cycle span for a mammalian cell?

Ans. About 24 hours.

2. Distinguish between cytokinesis from karyokinesis.

Ans. Karyokinesis is division of nucleus, while cytokinesis is division of cytoplasm.

3. Describe the events taking place during interphase.

Ans. Refer pages 609–610 of chapter 10.

4. What is G_0 (quiescent phase) of cell cycle?

Ans. When the cell becomes inactive, stops dividing and becomes specialized by differentiation.

5. Why is mitosis called equational division?

Ans. Because it keeps the chromosome number constant and genetic stability in the daughter cells.

6. Name the stage of cell cycle at which one of the following events occur :

(i) Chromosomes are moved to spindle equator.

(ii) Centromere splits and chromatids separate.

(iii) Pairing between homologous chromosomes takes place.

(iv) Crossing over between homologous chromosomes takes place.

Ans. (i) Metaphase stage.

(ii) Anaphase stage.

(iii) Zygotene stage of Prophase-I of meiosis.

(iv) Late Pachytene stage of Prophase-I of meiosis.

7. Describe the following :

(i) Synapsis; (ii) Bivalent; (iii) Chiasmata.

Draw a diagram to illustrate your answer.

Ans. (i) **Synapsis :** It is the process of pairing of homologous chromosomes. It starts during zygotene of Prophase-I and extends upto pachytene of Prophase-I of meiosis-I.

(ii) **Bivalent :** It is the pair of homologous chromosomes formed by synapsis. Its number is half to the number of chromosomes in a diploid organism.

(iii) **Chiasmata :** These are the X-shaped points of cross over between the non-sister chromatids of homologous chromosomes. These are formed during pachytene of Prophase-I of meiosis. These are sites of crossing over.

Refer Fig. 11 of chapter 10.

8. How does cytokinesis in plant cells differ from that in animal cells?

Ans. In plant cells, cytokinesis occurs by cell plate formation, while in animal cells, it occurs by cell furrow formation. Refer Table 1 of chapter 10.

9. Form examples where the four daughter cells from meiosis are equal in size and where they are found unequal in size.

Ans. During spermatogenesis in the testes of the mammals, a spermatogonium (sperm mother cell) undergoes meiosis and forms four daughter cells, called **spermatozoa,** which are equal in size, while during oogenesis in the ovary of the mammals, an oogonium (egg mother cell) undergoes meiosis and produces one large sized **ovum** and 2 or 3 small sized polar bodies.

10. Distinguish anaphase of mitosis from anaphase-I of meiosis.

Ans. In anaphase of mitosis, separating daughter chromosomes are single stranded chromatids, while in anaphase-I of meiosis, homologous chromosomes separate, each being formed of two sister - chromatids.

11. List the main differences between mitosis and meiosis.

Ans. Refer Table 4 of chapter 10.

12. What is significance of meiosis?

Ans. (i) It produces **haploid gametes** for sexual reproduction.

(ii) It produces **genetic variability** due to crossing over during pachytene stage of prophase–I and chance arrangement of bivalents at equator of metaphase-I.

(iii) It produces chromosomal and genomic mutations which act as sources of **useful variations** which help in evolution and improvement of race.

13. Discuss with your teacher about :

(i) Haploid insects and lower plants where cell division occurs, and

(ii) Some haploid cells in higher plants where cell division does not occur.

Ans. (i) Drones (males) of honey bee and lower plants like *Chlamydomonas*, *Spirogyra*, etc. are haploids. These produce haploid gametes by mitosis and not by meiosis.

(ii) Spermatozoa and ova of higher animals, and microspores and megaspores of higher plants do not undergo cell division.

14. Can there be mitosis without DNA replication in 'S'-phase?

Ans. There cannot be mitosis without DNA replication because trigger for mitosis is disturbance in nucleo-cytoplasmic ratio caused by DNA replication in S-phase. Mitosis restores the genetic material to species specific level.

15. Can there be DNA replication without cell division?

Ans. In salivary gland cells of *Drosophila*, the chromosomes are polytenic or multistranded because DNA replication is not followed by their separation as there is no cell division. This is called **endoduplication.**

16. Analyse the events during every stage of cell cycle and notice how the following two parameters change:

(i) Number of chromosomes (N) per cell.

(ii) Amount of DNA content (C) per cell.

Ans. (i) In G_1-phase, the number of chromosomes (N) per cell remains same and each chromosome is formed of one chromatid. In S-phase, each chromosome is formed of two sister chromatids joined at the centromere. Same condition continues in G_2-phase while in M-phase, sister chromatids separate and move to different cells but the number of chromosomes remains same in mitosis.

(ii) In G_1-phase, the amount of DNA content (C) per cell remains same but in S-phase it is doubled due to DNA replication. It remains double in G_2-phase but is halved in M-phase of cell cycle.

NCERT Exemplar Problems

A. MULTIPLE CHOICE QUESTIONS

1. Meiosis results in:
   (a) Production of gametes
   (b) Reduction in the number of chromosomes
   (c) Introduction of variation
   (d) all of the above
2. At which stage of meiosis does the genetic constitution of gametes is finally decided:
   (a) Metaphase I (b) Anaphase II
   (c) Metaphase II (d) Anaphase I
3. Meiosis occurs in organisms during:
   (a) Sexual reproduction
   (b) Vegetative reproduction
   (c) Both sexual and vegetative reproduction
   (d) None of the above
4. During anaphase-I of meiosis:
   (a) Homologous chromosomes separate
   (b) Non-homologous autosomes separate
   (c) Sister chromatids separate
   (d) Non-sister chromatids separate
5. Mitosis is characterised by:
   (a) Reduction division
   (b) Equal division
   (c) Both reduction and equal division
   (d) None of the above
6. A bivalent of meiosis-I consists of:
   (a) Two chromatids and one centromere
   (b) Two chromatids and two centromere
   (c) Four chromatids and two centromere
   (d) Four chromatids and four centromere
7. Cells which are not dividing are likely to be at:
   (a) G_1 (b) G_2
   (c) G_o (d) S phase
8. Which of the events listed below is not observed during mitosis?
   (a) Chromatin condensation
   (b) Movement of centrioles to opposite poles
   (c) Appearance of chromosomes with two chromatids joined together at the centromere.
   (d) Crossing over
9. Identify the wrong statement about meiosis:
   (a) Pairing of homologous chromosomes
   (b) Four haploid cells are formed
   (c) At the end of meiosis the number of chromosomes are reduced to half
   (d) Two cycle of DNA replication occurs
10. Select the correct statement about G_1 phase:
    (a) Cell is metabolically inactive
    (b) DNA in the cell does not replicate
    (c) It is not a phase of synthesis of macromolecules
    (d) Cell stops growing

ANSWERS

1. (d); **2.** (d); **3.** (a); **4.** (a); **5.** (b); **6.** (c); **7.** (c); **8.** (d); **9.** (d); **10.** (b).

HINTS OF SOME DIFFICULT MULTIPLE CHOICE QUESTIONS

2. (d) : Because Anaphase-I involves random separation of pairs of homologous chromosomes so producing all the possible combinations.

6. (c) : A bivalent is a pair of synapsed homologous chromosomes and each chromosome is formed of two sister chromatids so in a bivalent there are two chromosomes and four chromatids.

9. (d) : No DNA replication occurs in interkinesis or intrameiosis interphase.

B. VERY SHORT ANSWER TYPE QUESTIONS

1. Between a prokaryote and eukaryote, which cell has a shorter cell division time?

Ans. Prokaryotic cells like bacteria have shorter cell division time because of simpler cellular organisation.

2. Which of the phases of cell cycle is of longest duration?

Ans. Interphase (especially G_1 phase of interphase) of cell cycle.

3. Name a stain commonly used to colour chromosomes.

Ans. Carmine stain (e.g. Acetocarmine).

4. Which tissue of animals and plants exhibits meiosis?

Ans. Spermatocytes of testes and oocytes of ovaries in the animals. Microsporocytes of anthers and Megasporocyte of ovule of ovary of flowers in the Angiosperms.

5. Given that the average duplication time of *Escherichia coli* is 20 minutes, how much time will two *E-coli* take to become 32 cells?

Ans. One hour and twenty minutes.

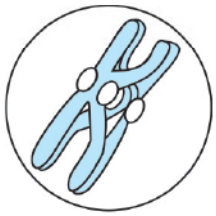
6. Which part of the human body should one use to demonstrate stages in mitosis?

Ans. Somatic cells of stratum germinativum of epidermis or epithelial cells of gut mucosa.

7. What attributes does a chromatid require to be classified as a chromosome?

Ans. It must have centromere or primary constriction and the kinetochore.

8. The diagram shows a bivalent at Prophase - I of meiosis. Which of the four chromatids can cross over?



Ans. Non-sister chromatids of homologous chromosomes.

9. If a tissue has at a given time 1024 cells, how many cycles of mitosis had the original parental single cell undergone?

Ans. Parental cell has to undergo ten mitotic divisions to produce 1024 cells.

10. An anther has 1200 pollen grains, how many pollen mother cells must have been there to produce them?

Ans. 300 Pollen mother cells undergo meiosis to produce 1200 pollen grains.

11. At what stage of cell cycle, does DNA synthesis take place?

Ans. During S-(synthetic) phase of interphase of cell cycle.

12. It is said that one cycle of cell division in human cells (eukaryotic cells) takes 24 hours. Which phase of the cycle, do you think occupies the maximum part of cell cycle?

Ans. Prophase of cell division is of longest duration out of 4 phases.

13. It is observed that heart cells do not exhibit cell division. Such cells do not divide further and exit __A__ phase to enter an inactive stage called __B__ of cell cycle. Fill in the blanks.

Ans. A = G_1 phase; B = G_0 phase.

14. In which phase of meiosis are the following formed? Choose the answers from hint points given below:

(a) Synaptonemal complex .....

(b) Recombination nodules .....

(c) Appearance/activation of enzyme recombinase .....

(d) Termination of Chiasmata .....

(e) Interkinesis .....

(f) Formation of dyad of cells .....

Hint: 1. Zygotene; 2. Pachytene; 3. Pachytene; 4. Diakinesis; 5. After Telphase-I/Before Telophase-II; 6. Telphase-I/After Meisis-I.

Ans. (a) Zygotene of Prophase-I.

(b) Pachytene of Prophase-I.

(c) Pachytene of Prophase-I.

(d) Diakinesis.

(e) Telophase-I/After Meiosis-I.

(f) Pachytene of Prophase-I.

C. SHORT ANSWER TYPE QUESTIONS

1. State the role of centrioles other than spindle formation.

Ans. In addition to formation of spindle apparatus, centrioles also:

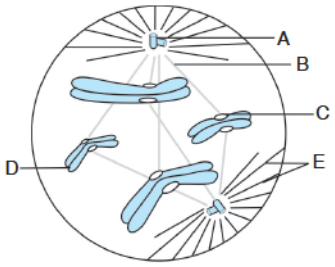
(i) Form the **Basal bodies** which give rise to cilia or flagella.

(ii) Distal centriole of spermatid forms **axoneme** of tail of sperm.

2. Mitochondria and plastids have their own DNA (genetic material). What is known about their fate during nuclear division like mitosis?

Ans. Both mitochondria and plastids have their own circular and naked DNA molecules due to which these organelles are capable of self-duplication during G_2 phase of interphase. These organelles are equally distributed in the daughter cells formed by M-phase.

3. Label the diagram and also determine the stage at which this structure is visible.



Ans. **A** = Centrioles; **B** = Chromosomal fibre

C = Kinetochore/Centromere;

D = Chromosome; **E** = Astral rays.

This stage is **Prophase**.

4. A cell has 32 chromosomes. It undergoes mitotic division. What will be the chromosome number (M) during metaphase? What would be the DNA content (C) during anaphase?

Ans. **(i)** At metaphase, there will be 32 chromosomes and each chromosome will be formed of 2 sister chromatids and the DNA content per chromosome will be 4 C.

(ii) At anaphase, there will be 46 daughter chromosomes, 32 moving forward each pole. Each daughter chromosome will be of only one chromatid and DNA content will be 2 C.

5. While examining the mitotic stage in a tissue, one finds some cells with 16 chromosomes and some with 32 chromosomes. What possible reasons could you assign to this difference in chromosome could have arisen from cells with 32 chromosomes or vice-versa?

Ans. In mitosis, cells with 16 chromosomes (each being formed of 2 sister chromatids) can form cells with 32 chromosomes at anaphase when sister chromatids separate and form daughter chromosomes.

But in Telophase, out of 32 chromosomes

16 chromosomes are reassembled at each pole to form daughter cells with 16 chromosomes.

6. The following events occur during the various phases of the cell cycle. Name the phase against each of the events.

(a) Disintegration of nuclear membrane .....

(b) Appearance of nucleolus .....

(c) Division of centromere .....

(d) Replication of DNA .....

Ans. **(a)** Prophase; **(b)** Telophase; **(c)** Anaphase; **(d)** S-phase of interphase.

7. Mitosis results in producing two cells which are similar to each other. What would be the consequence if each of the following irregularities occur during mitosis?

(a) Nuclear membrane fails to disintegrate.

(b) Duplication of DNA does not occur.

(c) Centromeres do not divide.

(d) Two nuclei present in same cell.

Ans. **(a)** As spindle is formed outside the nucleus, the chromosomes fail to arrange at the equator and separate.

(b) Cell-division (M-phase) does not occur.

(c) Daughter chromosomes (sister chromatids) fail to separate.

(d) Two nuclei present in same cell.

8. Both unicellular and multicellular organisms undergo mitosis. What are the differences, if any, observed in the process between the two?

Ans. Unicellular organisms undergo a simplified mitosis, called **promitosis**, in which spindle is formed inside the nucleus and nuclear membrane does not disappear. It is so as in these cells the centrioles are present inside the nucleus.

9. Name the pathological condition when uncontrolled cell division occurs.

Ans. Uncontrolled growth and cell division leads to tumour formation. This pathological condition is called **cancer.**

10. Two key events take place during S-phase in animal cells: DNA replication and duplication of centrioles. In which parts of the cell cycle do these events occur?

Ans. **(i)** DNA replication occurs **during S-phase** of interphase of cell cycle so that each chromosome is now formed of two sister chromatids joined at the centromere.

(ii) Duplication of centrioles occurs **during G_2 phase** of interphase of cell cycle.

11. Comment on the statement "Meiosis enables the conservation of specific chromosome number of each species even though the process per sec results in reduction of chromosome number."

Ans. Though meiosis results in reduction of chromosome number and produces the **haploid gametes** from diploid germ cells of the gonads. But it is always **followed by fertilization** which involves fusion of haploid gametes to restore original diploid chromosome number.

So meiosis and fertilization both work in coordination to conserve species specific chromosome number.

12. Name a cell that is found arrested in diplotene stage for months and years. Comment in 2-3 lines, how it completes cell cycle?

Ans. In oocytes of some vertebrates, meiosis is arrested at diplotene of meiosis-I for months and years. Meiosis is completed only under changed conditions of breeding season.

13. How does cytokinesis in plant cells differ from that in animal cells?

Ans. In dividing animal cells, cytokinesis occurs by **cell-furrow formation** in which cell furrow deepens centripetally to divide the cell while in dividing plant cells, cytokinesis occurs by **cell plate formation** in which cell plate is formed at centre and extends centrifugally.

D. LONG ANSWER TYPE QUESTIONS

1. Comment on the statement-Telophase is reverse of Prophase.

Ans. Prophase is first phase of karyokinesis while Telophase is the last phase of karyokinesis. Telophase is said to be reverse to Prophase because it involves the changes opposite to prophase e.g

(i) In prophase, chromatin fibres undergo dehydration and spirallization to form short and thick chromosomes while in Telophase the chromosomes undergo hydration and despirallization to change into long thread-like chromatin fibres.

(ii) Nuclear membrane and nuclei disappear in Prophase but reappear in Telophase.

(iii) Mitotic apparatus (spindle and asters) are formed in Prophase but disappear at Telophase.

2. What are the various stages of meiotic Prophase-I? Enumerate the chromosomal events during each stage.

Ans. Various stages of meiotic Prophase-I are:

(i) Leptotene. Chromatin fibres condense by dehydration and spirallization to form chromosomes.

(ii) Zygotene. It is characterised by **synapsis** (pairing of homologous chromosomes) and formation of **Synaptonemal complex dyads** (each chromosome formed of 2 sister chromatids) and **tetrads**.

(iii) Pachytene. It is characterised by formation of **recombination nodules** and **crossing over** between non-sister chromatids.

(iv) Diplotene. It is characterised by dissolution of synaptonemal complex and beginning of terminalisation (separation of homologous chromosome).

(v) Diakinesis. It is characterised by completion of terminalisation, disappearance of nuclear membrane and nucleoli and completion of mitotic apparatus.

3. Differentiate between the events of mitosis and meiosis.

Ans. Refer Table-4 of chapter no. 10.

4. Write brief note on the following:

(a) Synaptonemal complex. **(b) Metaphase plate.**

Ans. **(a) Synaptonemal complex.** It is an electron microscopic ladder like filamentous complex of nucleoproteins. It is formed between the homologous chromosomes during zygotene and helps in their synapsis. It extends upto pachytene and starts disappearing after crossing over and helps in desynapsis of homologous chromosomes.

(Refer Fig. 11 of chapter no. 10)

(b) **Metaphase plate.** The plane of alignment of chromosomes at the equator of spindle during metaphase of cell division is called **metaphase plate.** In mitosis, chromosomes arrange at equator in one metaphase plate, while in meiosis bivalents arrange at equator in two metaphase plates.

5. Write briefly the significance of mitosis and meiosis in multicellular organisms.

Ans. (i) Significance of Mitosis:

(a) Maintains chromosome number and linear heredity of organism.

(b) Helps in growth of zygote into adult.

(c) Provides new cells for repair, healing and regeneration.

(d) Restores nucleoplasmic ratio.

(e) Helps in longitudinal growth and secondary growth in plants.

(ii) Significance of meiosis:

(a) Produces haploid gametes or spores.

(b) Meiosis and fertilization coordinate to conserve chromosome number.

(c) Produces variations due to crossing over so helps in evolution.

6. An organism has two pairs of chromosomes (i.e. chromosome number = 4). Diagrammatically represent the chromosomal arrangement during different phases of meiosis-II.

Ans. Refer Fig. 14 of chapter - 10.

HOTS Higher Order Thinking Skills & Brain Twisting

QUESTIONS WITH ANSWERS

Very Short Answer Questions *One mark each*

1. Which events occur during S-phase of interphase?

Ans. DNA replication and biosynthesis of histones.

2. What happens to a cell lying in G_0 phase?

Ans. Either re-enters G_1 phase or undergoes differentiation and specialization.

3. State drawback of amitosis.

Ans. It causes unequal distribution of chromosomes in daughter cells.

4. What are kinetochores? State their function.

Ans. Kinetochores are two disc-like areas, one on either side of centromere and are sites for attachment of chromosomal fibres of the spindle.

5. At which stage of Meiosis, reduction of chromosome number occurs?

Ans. Anaphase-I.

6. What is mitotic apparatus?

Ans. Asters and spindle are collectively called mitotic apparatus.

7. What are phragmoplasts?

Ans. Phragmoplasts are elements of ER and Golgi complex which form cell plate during cytokinesis of a dividing plant cell.

8. Name the meiotic stage in which synapsis occurs.

Ans. Zygotene subphase of prophase-I.

9. Define disjunction.

Ans. Separation of homologous chromosomes during Anaphase-I is called disjunction.

10. Give the technical name for a network of nucleoproteinous fibres present between the synapsed chromosomes.

Ans. Synaptonemal complex.

Short Answer Questions *Two marks each*

1. What is trigger for initation of cell division?

Ans. Trigger for initiation of cell division is **DNA replication** which occurs during S-phase of interphase. This disturbs nuclear cytoplasmic ratio and triggers the cell division.

2. In which respects, interkinesis differs from interphase?

Ans. Interkinesis is intrameiotic interphase between meiosis-I and meiosis-II. In interkinesis, there is no S-phase so no DNA replication.

3. State the differences between Anaphase-I and Anaphase-II.

Ans. Anaphase-I involves separation of homologous chromosomes to opposite poles (called **disjunction**) but each chromosome is still formed of two sister chromatids. Anaphase-II involves separation of chromatids of each chromosome.

4. Enlist the differences between mitosis in plant cell and in animal cell.

Ans. (i) Spindle formed is anastral in plant cell (i.e. with no asters) while it is amphiastral in animal cell.

(ii) Cytokinesis occurs by cell plate formation in plant cell, while it occurs by cell furrow formation in animal cell.

5. Why mitosis has no role in evolution?

Ans. As no crossing over and recombination of genes occur in mitosis so mitosis keeps genetic homogeneity and no variations are produced.

6. Meiosis is essential for keeping the chromosome number constancy generation after generation.

Ans. In sexual reproduction, meiosis is followed by fertilization. Meiosis changes diploidy to haploidy while fertilization involves fusion of haploid gametes to restore diploidy.

Short Answer Questions *Three marks each*

1. Define interphase. Enlist the events occurring in its subphases.
2. What is mitosis? Discuss the trigger for mitosis and its significance.
3. In which phases, the following events occur:
   (i) Suspended metabolism (ii) Reappearance of nucleolus
   (iii) Synapsis (iv) Crossing over
   (v) Dysjunction
4. Draw diagrams to show various subphases of prophase of meiosis-I.

Long Answer Questions *Five marks each*

1. Explain the process of mitosis with the help of neat and labelled diagrams. Give its significance.
2. Differentiate between mitosis and meiosis.

QUICK MEMORY TEST

A. Say True or False

Write 'True' or 'False':

1. Meiosis occurs in root tip.
2. Centromeres split and chromatids move apart during anaphase.
3. Exchange of segments of chromosomes occurs during meiosis.
4. Chromosomes line up at the equator of spindle in anaphase.
5. Anaphase-I chromosomes having distinct chromatids are called dyad.
6. Disjunction is the act of separation of homologous chromosomes during Anaphase.
7. Transition phase between prophase and metaphase is called late prophase.
8. Swollen areas present on the prophase-I chromosomes are called chromatin.
9. Nucleoprotein complex present between synapsed chromosomes is called synaptinemal complex.
10. In anaerobic tissues, glycolysis provides energy for cell division.
11. Chromatids become clear only during diakinesis of prophase-I.
12. During meiosis, the state of nucleus having long thread-like chromatin fibres is called interkinesis.
13. The number of bivalents is half the number of total chromosomes.
14. The cell cycle involves amitosis, mitosis and meiosis.
15. Anastral spindle occurs in animal cells.
16. Mitosis occurs only in multicellular organisms.
17. Both mitosis and meiosis occur in germ cells.

B. Complete the missing links

1. Somatic cells multiply by ..... .
2. The region of the attachment of chromosomes to spindle fibres is called ..... .
3. The spindle formed in the dividing plant cell is ..... .
4. Asters are formed from ..... .
5. ..... is the pairing of homologous chromosomes during zygotene.
6. Exchange of genetic material between non-sister chromatids is ..... .
7. Cell-plate is formed of smaller units called ..... .

8. G_1, S and G_2 are sub-phases of ..... .
9. Chromosomes line up at the equator of the spindle in ..... .
10. In meiosis, the reduction of DNA amount per chromosome occurs in ..... .
11. Spindle fibres are chemically formed of ..... .
12. ..... is the division of nucleus while ..... is the division of cytoplasm.
13. ..... of plant flowers are the best material to study meiosis.
14. Chiasmata are the expressions of ..... .
15. A cell has 20 chromosomes. After meiosis ..... chromosomes are present in the daughter cells.
16. In animal cytokinesis, the cleavage extends ..... .
17. Colchicine arrests cell division in ..... stage.

C. Choose the correct alternative

1. Mitochondria and centrioles duplicate in **$G_0/G_1/G_2$ phase** of interphase.
2. Interkinesis lies between **two mitotic division/meiosis-I and meiosis-II**.
3. Genetic homogeneity is kept by **mitosis/meiosis.**
4. Mitosis occurs in **only somatic cells/both somatic and germ cells.**
5. Point of attachment of chromosomal fibre of spindle is **kinetochore/centromere.**
6. In anaphase, moving V-shaped chromosome is **metacentric/submetacentric.**
7. In animal cell, cytokinesis occurs by **cell plate/cell furrow formation.**
8. In plant cell, spindle is **anastral/amphiastral.**
9. Meiosis-I is also called **homotypical/heterotypical divison.**
10. Synaptonemal complex appears in **Leptotene/zygotene** and disappears in **pachytene/diplotene.**
11. Terminalisation is completed in **diplotene/diakinesis.**
12. Dysjunction occurs in **Anaphase-I/Anaphase-II.**
13. Pairing of homologous chromosomes is called **synapsis/desynapsis.**
14. Haploidy in DNA amount per chromosome occurs in **Anaphase-I/Anaphase-II.**
15. Humans have **gametic meiosis/zygotic meiosis.**

Answers QUICK MEMORY TEST

A. Say True or False

1. False; 2. True; 3. True; 4. False; 5. True; 6. True; 7. False; 8. False; 9. True; 10. True; 11. False; 12. True; 13. True; 14. False; 15. False; 16. False; 17. True.

B. Complete the missing links

1. Mitosis; 2. Centromere; 3. Anastral; 4. Centrosome; 5. Synapsis; 6. Crossing-over; 7. Phragmoplasts; 8. Interphase; 9. Metaphase; 10. Anaphase-II; 11. Tubulin protein; 12. Karyokinesis, cytokinesis; 13. Anthers; 14. Crossing over; 15. 10; 16. Centripetally; 17. Metaphase.

C. Choose the correct alternative

1. G_2 phase; 2. Meiosis-I and Meiosis-II; 3. Mitosis; 4. Both somatic and germ cells; 5. Kinetochore; 6. Metacentric; 7. Cell furrow formation; 8. Anastral; 9. Heterotypical division. 10. Zygotene, Pachytene; 11. Diakinesis; 12. Anaphase-I; 13. Synapsis; 14. Anaphase-II; 15. Gametic meiosis.

REVISION EXERCISES

Very Short Answer Questions

One mark each

1. Why is amitosis called incipient cell division?
2. Name four sub-phases of cell-cycle.
3. Give the terms for direct cell division, equational division and reductional division.
4. Name the stages of synapsis and crossing over.
5. Give the terms for nuclear division and cytoplasmic division.

6. Name the cell divisions which help in growth and recombination of genes.
7. Which two types of fibres are found in the spindle?
8. Define chiasmata.
9. In which phase of interphase, DNA replication occurs?
10. Which type of cell division occurs in meristematic cell of root apex?
11. What is cell cycle?
12. Name the stage during which astral and spindle fibres disappear and nuclear membrane and nucleoli reappear.
13. Name the sub-phases of prophase-I of Meiosis.
14. Which type of coiling is found in mitosis and meiosis?
15. What is kinetochore?
16. What are meiocytes?
17. In which stage, actual reduction of chromosome number occurs in meiosis?
18. Give the term for the failure of separation of homologous chromosomes.
19. Define karyokinesis.
20. What is disjunction?
21. Give the significance of synaptinemal complex.
22. What is significance of meiosis-II?
23. Define cytokinesis.
24. What is congression?
25. Define crossing over.

ANSWERS

1. Because it is simplest type of cell division in which there is no condensation of chromatin fibres and no formation of spindle; **2.** G_1, S, G_2 and M-Phase; **3.** Amitosis, Mitosis and Meiosis; **4.** Zygotene, Pachytene; **5.** Karyokinesis, cytokinesis; **6.** Mitosis, Meiosis; **7.** Chromosomal fibres, Continuous fibres; **8.** X-shaped points which are sites of crossing-over between non-sister chromatids; **9.** S-Phase; **10.** Mitosis; **11.** Sum of changes which occur during cell growth and cell division; **12.** Telophase; **13.** Leptotene, Zygotene, Pachytene, Diplotene and Diakinesis; **14.** Mitosis- plectonemic coiling, Meiosis- paranemic coiling; **15.** A discoidal area of the centromere and the site of attachment of chromosomal fibre; **16.** The cells undergoing meiosis; **17.** Anaphase-I; **18.** Non-disjunction; **19.** Division of nucleus; **20.** Separation of homologous chromosomes during anaphase-I; **21.** It helps in pairing and synapsis of homologous chromosomes during zygotene stage of Prophase-I; **22.** It brings haploidy in DNA amount of the chromosomes; **23.** Division of cytoplasm; **24.** Movement of chromosomes towards the equatorial plate of the spindle; **25.** Exchange of genetic material between the non-sister chromatids of homologous chromosomes during pachytene stage of Prophase-I.

Short Answer Questions

Two marks each

1. Name three phases of interphase. Give one major event of each phase.
2. Why is mitosis called equational division? Give the occurrence of mitosis.
3. What is kinetochore? Give its function.
4. Give two advantages of mitosis.
5. How does anastral and amphiastral spindle differ from each other?
6. Define meiosis. Give the occurrence of meiosis.
7. Distinguish between metaphase of mitosis and metaphase-I of meiosis.
8. Why is meiosis essentially in sexually reproducing organisms?
9. Name the forces which help in chromosomal movement during cell division.
10. What is interphase? Why was it previously known as resting phase?
11. What is G_0-phase? What changes occur in it?
12. Give the structure of spindle apparatus.
13. Distinguish between plant and animal cell mitosis.
14. What is disjunction? Describe the stage when it occurs.
15. Why is meiosis called the reductional division, whereas mitosis is called equational division?
16. What is synaptonemal complex? Give its significance.
17. Differentiate between gametic meiosis and zygotic meiosis.
18. Define the term synapsis. Name the stage of cell cycle when it occurs.
19. Define the term crossing-over. Name the stage of cell cycle when it occurs.
20. Define the term chiasmata. Name the stage of Prophase-I when it occurs.

ANSWERS

1. G_1 (Synthesis of RNA, ATP, proteins, etc.); S (DNA replication synthesis of histones); G_2 (synthesis of spindle proteins, RNAs, ATP and duplication of mitochondria, plastids).
2. It keeps the chromosome number constant. It occurs in somatic cells.
3. It is a disc-like area on each chromatid and is site of attachment of spindle microtubules.
4. Keeps chromosome number constant and helps in growth and repair of body tissues.
5. Anastral spindle is found in dividing plant cells and has no asters, while amphiastral spindle is found in dividing animal cells and has two asters, one at each pole.
6. Meoisis is reductional division in which cell divides twice and produces 4 haploid cells, each having half the chromosome number than in parental cell. It occurs in microsporocytes of anthers and ovules.
7. In metaphase of mitosis, the chromosomes arrange in **one equatorial plate** and **centromeres lie at the equator** while their arms are directed towards opposite poles. In metaphase–I of meiosis, bivalents are arranged to form **two equatorial plates** and centromeres of homologous chromosomes are towards the poles while their arms lie on the equator;
8. Meiosis reduces the chromosomes to half as it is followed by fertilization which restores diploidy. If in this gametes are formed by mitosis and not by meiosis, then the **gametes will be diploid** which will **result tetraploidy** after their fusion during fertilization;
9. Contraction of chromosomal fibres, stretching of continuous fibres, repulsion between centromeres of daughter chromosomes and elongation of interzonal fibres.
10. **(i) Interphase** is the period between the end of one cell division to the beginning of next cell division.
    (ii) It was earlier misnomerly called **resting phase** because no visible change occurs in the cell during this period.
11. **(i)** G_0 is the state of arrested condition and is also called **quiescent stage.**
    (ii) During G_0 phase, cells undergo cell differentiation and specialization to perform the specific function.
12. **Spindle apparatus** of dividing animal cell is **amphiastral** and is formed of a spindle and two asters. Spindle is formed of two types of spindle fibres : Chromosomal fibres and continuous fibres, while each aster is formed of two centrioles surrounded by radially arranged astral rays.
13. Refer Table 2 of chapter 10.
14. **Disjunction** is the separation of homologous chromosomes which occurs during anaphase-I of meiosis.
15. Because in meiosis, the chromosome number and DNA amount are halved than those of normal parental cell so is called **reductional division,** while in mitosis, the chromosome number and DNA amount are kept constant so is called **equational division.**
16. **(i) Synaptinemal complex** is a filamentous ladder-like nucleoproteinous complex formed between the paired homologous chromosomes during zygotene stage of Prophase-I.
    (ii) It helps in pairing and synapsis between the homologous chromosomes.
17. **Gametic meiosis** occurs in diploid adults (*e.g.* all the animals except protozoans) during gametogenesis in the gonads so produces haploid gametes, while **zygotic meiosis** occurs in haploid adults (*e.g.* Algae, Fungi, Bryophytes and Protozoans) during the germination of zygote.
18. Pairing of homologous chromosomes is called **synapsis.** It occurs during zygotene of Prophase-I of meiosis.
19. Exchange of genetic material between non-sister chromatids of homologous chromosomes is called **crossing over.** It occurs during pachytene of Prophase–I of meiosis.
20. Points of crossing over are called **chiasmata**. It occurs during pachytene of Prophase-I of meiosis.

Short Answer Questions

Three marks each

1. How does cell division of a typical plant cell differ from that of a typical animal cell?
2. Explain the significance of meiosis.
3. What are homologous chromosomes? What happens to homologues during meiosis?
4. Anaphase-I of meiosis differs from anaphase of mitosis in one essential way. Describe the difference and explain how it affects the daughter cells.
5. Why does a multicellular organism require two types of cell division? Which of two produces the greater number of cells?
6. Give the sequence of events occurring during prophase of mitosis.
7. Enumerate the significance of Mitosis?
8. Why do we term meiosis-I as reductional division and mitosis as equational division?
9. Describe types of mitosis.
10. Differentiate three types of meiosis.

11. List the most important feature of the following stages :
    (i) S-phase; (ii) Zygotene; (iii) Pachytene; (iv) Anaphase-I.
12. Describe prophase of Meiosis-I with neat and labelled diagrams.
13. Differentiate between mitosis and meiosis.

Long Answer Questions

Five marks each

1. Describe the events taking place during interphase.
2. A well known biologist stated that life history of an organism can be summed up as "gametic fusion, equational division and reductional division." Comment.
3. Say a plant X has 2N = 8 chromosomes. Sketch the various stages of meiosis in this plant.
4. Discuss prophase-I of meiosis-I with the help of well labelled sketches.
5. Describe the types of meiosis.
6. Bring out differences between mitosis and meiosis.
7. Draw labelled sketches to depict mitosis in a plant cell.
8. What are homologous chromosomes? What happens to homologous chromosomes during meiosis?
9. Define amitosis. Describe the mechanism and drawbacks of amitosis.
10. Why does a multicellular organism require two types of cell division? Which of the two, produces the greater number of cells?

COMPETITION FILE OBJECTIVE TYPE QUESTIONS

A. MULTIPLE CHOICE QUESTIONS (MCQs):

(From AIPMT & Other Competitive Examinations)

1. The replication of DNA is a pre-requisite for a eukaryotic cell to undergo division. During the cell cycle, the DNA replicates in :
   (a) S-phase (b) G_1-phase (c) G_2-phase (d) M-phase *(AFMC 2007)*
2. Crossing over that results in genetic recombination in higher organisms occurs between :
   (a) Sister chromatids of a bivalent (b) Non-sister chromatids of a bivalent
   (c) Two daughter nuclei (d) Two different bivalents *(Manipal 2007)*
3. In the somatic cell cycle :
   (a) In G_1-phase, DNA content is double the amount of DNA of original cell
   (b) DNA replication occurs in S-phase
   (c) A short interphase is followed by a long M-phase
   (d) G_2-phase follows mitotic phase *(Manipal 2007)*
4. If you are provided with root tips of onion in your class and are asked to count the chromosomes, which of the following stages can you most conveniently look into?
   (a) Metaphase (b) Telophase (c) Anaphase (d) Prophase *(Manipal 2007)*
5. Differentiated cell remains at which stage?
   (a) G_1 (b) G_2 (c) G_0 (d) M *(DPMT 2007)*
6. Centromere is required for :
   (a) Transcription (b) Crossing over
   (c) Cytoplasmic cleavage (d) Movement of chromosomes towards poles *(JIPMER 2007)*
7. The number of mitotic cell divisions required to produce 256 cells from single cell would be :
   (a) 10 (b) 12 (c) 6 (d) 8 *(KCET 2007)*
8. In meiosis-I, a bivalent is an association of :
   (a) Four chromatids and four centromeres (b) Two chromatids and two centromeres
   (c) Two chromatids and one centromere (d) Two chromatids and four centromeres
   (e) Four chromatids and two centromeres *(Kerala PMT 2007)*
9. In meiosis, chromosome number becomes :
   (a) Half of its parent chromosome number (b) Same as that of parent chromosome number
   (c) One fourth of its parent chromosome number (d) None of the above *(CPMT 2007)*
10. A cell plate is laid during :
    (a) Cytokinesis (b) Karyokinesis (c) Interphase (d) None of these *(CPMT 2007)*
11. Sudden and abnormal mitosis in an organ will frequently lead to :
    (a) Zygote (b) Cancer (c) New organ (d) Gastrula *(CPMT 2007)*

12. Mitotic spindle has main protein :
(a) Tubulin (b) Myosin (c) Tropomyosin (d) Dynein *(MP-PMT 2007)*

13. DNA replicates during :
(a) Prophase (b) S-phase (c) G_1-phase (d) G_2-phase *(Orissa JEE 2007)*

14. In mitosis, the number of chromosome sets in daughter cells will be :
(a) Different from parent cells (b) Half of the parent cells
(c) Double of the parent cells (d) Same as in parent cells *(Orissa JEE 2007)*

15. In meiosis, synapsis occurs during :
(a) Interphase (b) Prophase (c) S-phase (d) Leptotene *(Orissa JEE 2007)*

16. Which cell organelle is not bound by any membrane?
(a) Mitochondria (b) Chloroplast (c) ER (d) Ribosome *(Orissa JEE 2007)*

17. Cell division of bacteria is of :
(a) Mitotic (b) Meiotic (c) Amitotic (d) None of these
(Orissa JEE 2007)

18. Which of the following organelles is common to plants and animals?
(a) Chloroplast (b) Centriole (c) Mitochondria (d) Cell wall *(Orissa JEE 2007)*

19. Which one of the following precedes reformation of the nuclear envelope during M-phase of the cell cycle?
(a) Decondensation from chromosomes and reassembly of nuclear lamina
(b) Transcription from chromosomes and reassembly of nuclear lamina
(c) Formation of contractile ring and formation of the phragmoplast
(d) Formation of contractile ring and transcription from chromosomes *(AFMC & AIIMS 2008)*

20. When synapsis is complete all along the chromosome, the cell is said to have entered a stage called :
(a) Zygotene (b) Pachytene (c) Diplotene (d) Diakinesis *(AFMC 2008)*

21. Match list-I and list-II and select the correct answer :

List-I (Phase of Meiosis)	List-II (Event that occurs)
1. Prophase-I	Crossing over occurs
2. Metaphase-II	Sister chromatids migrate to opposite poles
3. Anaphase-I	Homologous chromosomes line up at equator in pairs
4. Telophase-II	Condensation of chromatin fibres

(a) 1, 2 and 3 are correct (b) 1 and 2 are correct (c) 2 and 4 are correct (d) 1 and 3 are correct
(BHU 2008)

22. Spindle fibres are made up of :
(a) Tubulin (b) Humulin (c) Intermediate filament (d) Flagellin *(BHU 2008)*

23. Mitosis is :
(1) Reduction in chromosome number (2) Karyokinesis
(3) Formation of four daughter nuclei (4) Cytokinesis
(a) 1, 2 and 3 are correct (b) 1 and 2 are correct (c) 2 and 4 are correct (d) 1 and 3 are correct
(BHU 2008)

24. Variations appear during meiosis due to :
(1) Independent assortment (2) Crossing over (3) Linkage (4) Glycolysis
(a) 1, 2 and 3 are correct (b) 1 and 2 are correct (c) 2 and 4 are correct (d) 1 and 3 are correct
(BHU 2008)

25. Consider the following statements :
(1) In plant cells, cytokinesis starts with the formation of phragmoplasts
(2) Phragmoplast comprises interzonal microtubules and Golgian vesicles
(3) Primary cell wall is produced by microtubules
(4) Phragmoplasts are formed from the nucleus
(a) 1, 2 and 3 are correct (b) 1 and 2 are correct (c) 2 and 4 are correct (d) 1 and 3 are correct
(BHU 2008)

26. Main protein of mitotic spindle fibres is ;
(a) Tubulin (b) Myosin (c) Tropomyosin (d) Dynein *(Har. PMT 2008)*

27. Crossing over occurs in :
(a) Zygotene (b) Leptotene (c) Pachytene (d) Diplotene *(Har. PMT 2008)*

28. Pick the correct statements :

A. Mitosis takes place in somatic cells while meiosis takes place in germ cells

B. During mitosis, DNA replicates once for one cell division while in meiosis, the DNA replicates twice for two cell divisions

C. Mitosis and meiosis occur both in sexually and asexually reproducing organisms

(a) A only (b) B only (c) C only

(d) A & B only (e) B & C only *(Kerala PMT 2008)*

29. In meiosis, the chromosomes replicate during :

(a) Prophase (b) Metaphase (c) Anaphase (d) Interphase *(Orissa JEE 2008)*

30. Chromosomes are visible with chromatids at one of the following phases of mitosis :

(a) Interphase (b) Prophase (c) Metaphase (d) Anaphase *(J&K-CET 2008)*

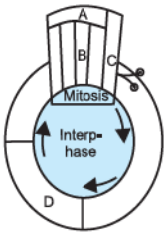
31. Which of the following sequence is a correct one for a meiotic cell cycle?

(a) $G_1 \rightarrow S \rightarrow G_2 \rightarrow M \rightarrow G_1$ (b) $G_1 \rightarrow G_2 \rightarrow S \rightarrow M \rightarrow G_2$ (c) $G_2 \rightarrow S \rightarrow G_1 \rightarrow M \rightarrow G_2$ (d) $S \rightarrow G_1 \rightarrow G_2 \rightarrow M \rightarrow S$ *(WB-JEE 2008)*

32. Chromosomes replicate in which stage of meiosis?

(a) Prophase-I (b) Prophase-II (c) Telophase (d) Interphase *(WB-JEE 2008)*

33. Given below is a schematic break up of the phases/stages of cell cycle.



Which one of the following is correct indication of the stage/phase in the cell cycle?

(a) B-Metaphase (b) C-Karyokinesis (c) D-Synthetic phase (d) A-Cytokinesis *(CBSE 2009)*

34. Synapsis occurs between:

(a) A male and a female gamete (b) mRNA and ribosomes

(c) Spindle fibres and centromere (d) Two homologous chromosomes *(CBSE 2009)*

35. G_1, G_2 and S phases are seen in which phase of the cell cycle?

(a) Metaphase (b) Prophase (c) Interphase (d) Anaphase *(AFMC 2009)*

36. During the G_1-phase of cell division :

(a) RNA and proteins are synthesized (b) Pre-mitotic DNA is synthesized

(c) Post-mitotic DNA is synthesized (d) Cell undergoes duplication *(CPMT 2009)*

37. Crossing-over occurs during :

(a) Leptotene (b) Zygotene (c) Pachytene (d) Diplotene *(CPMT 2009)*

38. Best material for the study of mitosis in laboratory is :

(a) Anther (b) Root tip (c) Leaf tip (d) Ovary *(CPMT 2009)*

39. Polyploidy can be induced artificially by:

(a) Colchicine (b) Inbreeding

(c) Line breeding (d) Self pollination *(DPMT 2009)*

40. Recombination is involved in the process of :

(a) Cytokinesis (b) Spindle formation

(c) Crossing over (d) Chromosome duplication *(DPMT 2009)*

41. Which of the following is unique to mitosis and not a part of meiosis?

(a) Homologous chromosomes behave independently (b) Chromatids separate during anaphase

(c) Homologous chromosomes pair and form bivalents (d) Homologous chromosomes crossover *(DPMT 2009)*

42. Which of the following characters is related with telophase?

(a) Formation of nuclear membrane (b) Formation of nucleolus

(c) Elongation of chromosomes (d) Formation of two daughter nuclei *(BVP–2009)*

43. Chromosomes are arranged along the equator during :
(a) Prophase (b) Metaphase (c) Anaphase (d) Telophase ***(BVP– 2009)***

44. DNA replication occurs during which part of cell cycle?
(a) G_1-phase (b) S-phase (c) G_2-phase (d) Dividing phase
(AFMC & UP-CPMT 2010)

45. Compare the statements A and B.
Statement A : Synthesis of DNA takes place in the S-phase of interphase.
Statement B : Every chromosome, during metaphase, has two chromatids.
Choose the correct description :
(a) Statement A is wrong and B is correct
(b) Statement A is correct and B is wrong
(c) Both the statements A and B are correct and A is the reason for B
(d) Both the statements A and B are correct and A is not the reason for B ***(KCET 2010)***

46. Amitosis is shown by :
(a) Bacteria (b) *Euglena* (c) *Syllis* (d) *Hydra* ***(UP-CPMT 2010)***

47. During which stage of meiosis, synaptinemal complex is formed?
(a) Pachytene (b) Diplotene (c) Diakinesis (d) Zygotene ***(UP-CPMT 2010)***

48. Which of the following events takes place during diplotene of Prophase-I of meiosis?
(a) Compaction of chromosomes
(b) Formation of synaptinemal complex
(c) Formation of recombinational nodules
(d) Dissolution of synaptinemal complex ***(DUMET 2010)***

49. The exchange of segments of non-sister chromatids between chromosomes of a homologous pair is called :
(a) Transformation (b) Translocation (c) Crossing over (d) Chromosomal aberration
(DUMET 2010)

50. Crossing over may result in :
(a) Addition of genetic material (b) Deletion of genetic material
(c) Exchange of genetic material (d) All of these ***(MP-PMT 2010)***

51. In mitosis, the chromosomes can be seen most distinctly during :
(a) Interphase (b) Prophase (c) Metaphase (d) Telophase ***(MP-PMT 2010)***

52. During meiosis-I, the bivalent chromosomes clearly appear as tetrads during :
(a) Diakinesis (b) Diplotene (c) Leptotene
(d) Zygotene (e) Pachytene ***(Kerala PMT 2010)***

53. Which phase comes in between G_1 and G_2 phases of cell cycle?
(a) M-phase (b) G_0-phase (c) S-phase (d) Interphase ***(WB-JEE 2010)***

54. Cell division cannot be stopped in which phase of the cell cycle?
(a) G_1-phase (b) G_2-phase (c) S-phase (d) Prophase ***(WB-JEE 2010)***

55. Chiasmata formation takes place during :
(a) Prophase-I (b) Metaphase-I (c) Anaphase-I (d) Telophase-I ***(AMU 2010)***

56. Select the correct option with respect to mitosis :
(a) Chromatids separate but remain in the centre of the cell in anaphase
(b) Chromatids start moving towards opposite poles in telophase
(c) Golgi complex and endoplasmic reticulum are still visible at the end of prophase
(d) Chromosomes move to the spindle equator and get aligned along equatorial plate in metaphase ***(CBSE 2011)***

57. Select the correct match :
A. S-phase = DNA replication B. Zygotene = Synapsis
C. Diplotene = Crossing over D. Meiosis = Both haploid and diploid cells
(a) A & B (b) C & D (c) C & E
(d) A, C & E (e) A & D ***(Kerala PMT 2011)***

58. During meiosis, the alleles of the parental pair separate or segregate from each other. How many allele(s) are then transmitted to a gamete?
(a) Four (b) Two (c) Six
(d) One (e) Eight (*Kerala PMT 2011*)

59. The stage between two meiotic divisions is called :
(a) Interphase (b) Cytokinesis (c) Interkinesis
(d) Karyokinesis (e) Diakinesis (*Kerala PMT 2011*)

60. During gamete formation, the enzyme recombinase participates during:
(a) Metaphase-I (b) Anaphase-II (c) Prophase-I (d) Prophase-II (*CBSE 2012*)

61. The given figure is the representation of a certain event at a particular stage of a type of cell division. What is that stage?

(a) Prophase-I during meiosis (b) Prophase-II during meiosis
(c) Prophase of mitosis (d) Both prophase and metaphase of mitosis (*CBSE 2012*)

62. Microtubule depolymerizing drug such as colchicine is expected to:
(a) Inhibit spindle formation during mitosis (b) Inhibit cytokinesis
(c) Allow mitosis beyond metaphase (d) Induce formation of multiple contractile rings (*AIIMS 2012*)

63. Which of the following statements is incorrect about G_0 phase?
(a) Mitosis occurs after G_0 phase (b) Biocatalysts can be used to exit G_0 phase
(c) Cell volume goes on increasing during G_0 phase (d) Cell metabolism occurs continuously in G_0 phase (*AIIMS 2012*)

64. Beads on string like structures of A are seen in B, which further condense to form chromosomes in C stage of cell division. What are A, B and C ?

A	B	C
(a) chromonema	chromatin	Metaphase
(b) chromatin	chromatid	Metaphase
(c) chromonema	chromosome	Anaphase
(d) chromonema	chromatin	Anaphase

(*AIIMS 2012*)

65. Colchicine is obtained from which of the following families?
(a) Poaceae (b) Brassicaceae (c) Malvaceae (d) Liliaceae (*AFMC 2012*)

66. A stage in mitosis that starts towards the middle of anaphase and is completed with the telophase is:
(a) Cytokinesis (b) Karyokinesis (c) Crossing over (d) Interkinesis (*AFMC 2012*)

67. If the number of chromosomes in root cell is 14, then what will be the chromosome number in synergids?
(a) 14 (b) 21 (c) 7 (d) 28 (*BHU 2012*)

68. The term synaptinemal complex refers to the site of:
(a) Chromatid separation (b) Spindle attachment
(c) Replication (d) Chromosome alignment and recombination (*BHU 2012*)

69. The number of autosomes in a normal human cell is:
(a) 44 (b) 45 (c) 46 (d) 48 (*J&K CET 2012*)

70. The chromosomes become gradually visible with compaction of chromatin during the meiotic stage:
(a) Diplotene (b) Leptotene (c) Zygotene (d) Pachytene (*AMU 2012*)

71. Find the correctly matched pairs and choose the correct option:
(A) Leptotene – The chromosomes become invisible
(B) Zygotene – Pairing of homologous chromosomes
(C) Pachytene – Dissolution of the synaptonemal complex takes place
(D) Diplotene – Bivalent chromosomes appear as tetrads
(E) Diakinesis – Terminalization of chiasmata takes place
(a) A and B are correct (b) B and D are correct (c) B and E are correct (d) B and C are correct
(e) C and D are correct (*Kerala-PMT 2012*)

72. Which of the following events are not characteristic features of telophase?
(A) Chromosome material condenses to form compact mitotic chromosomes
(B) Nucleolus, Golgi complex and ER reform

(C) Nuclear envelope assembles around the chromosome clusters

(D) Centromeres split and chromatids separate

(E) Chromosomes cluster at opposite spindle poles and their identity as discrete elements is lost

(a) A, B and D only (b) A and D only (c) B and C only (d) C, D and E only
(e) A and B only. *(Kerala PMT 2012)*

73. The complex formed by a pair of synapsed homologous chromosomes is called:

(a) Equatorial plate (b) Kinetochore (c) Bivalent (d) Axoneme *(NEET 2013)*

74. Meiosis takes place in:

(a) Meiocyte (b) Conidia (c) Gemmule (d) Megaspore *(NEET 2013)*

75. A stage in cell shown in the figure. Select the answer which gives correct identification of the stage with characteristics:

(a) Telophase	Nuclear envelope reforms, Golgi complex reforms.
(b) Late anaphase	Chromosomes move away from equatorial plate, golgi complex not formed.
(c) Cytokinesis	Cell plate formed, mitochondria distributed between daughter cells.
(d) Telophase	Endoplasmic reticulum and nucleolous do not get reformed.

(NEET 2013)

76. Onion root tip during metaphase stage of mitosis, the number of kinetochores will be:

(a) 4 (b) 8 (c) 16 (d) 28 *(AMU 2013)*

77. During which phase (s) of cell cycle, amount of DNA in a cell remains at 4C level if the initial amount is denoted as 2C?

(a) Only G_2 (b) G_2 and M (c) G_0 and G_1 (d) G_1 and S *(AIPMT 2014)*

78. In S-phase of the cell cycle:

(a) Chromosome number is increased (b) Amount of DNA is reduced to half
(c) Amount of DNA is doubled (d) Amount of DNA is kept same *(AIPMT 2014)*

79. The enzyme recombinase is required at which stage of meiosis?

(a) Diplotene (b) Diakinesis (c) Pachytene (d) Zygotene *(AIPMT 2014)*

80. Nuclear membrane is a derivative of:

(a) SER (b) Membrane of Golgi complex
(c) Microtubules (d) RER *(AIPMT 2015)*

81. Select the correct option :

	Column-I	Column-II
1.	Synapsis aligns homologous chromosomes	(i) Anaphase-II
2.	Synthesis of RNA and proteins	(ii) Zygotene
3.	Action of enzyme recombinase	(iii) G_2-phase
4.	Centromeres do not separate but chromatids more towards opposite poles.	(iv) Anaphase-I
		(v) Pachytene

(a) 1 (ii), 2 (i), 3 (iii), 4 (iv) (b) (ii), 2 (iii), 3 (v), 4 (iv)
(c) 1 (i), 2 (ii), 3 (v), 4 (iv) (d) 1 (ii), 2 (iii), 3 (iv), 4 (v) *(AIPMT 2015)*

82. A somatic cell that has just completed the S-phase of its cell cycle, as compared to gamete of the same species:

(a) Twice the number of chromosomes and twice the amount of DNA
(b) Same number of chromosomes but twice the amount of DNA
(c) Twice the number of chromosomes but four times the amount of DNA
(d) Four times the number of chromosomes and twice the DNA amount *(AIPMT 2014)*

83. Arrange the following events of meiosis in correct sequence:

(i) Crossing over (ii) Synapsis (iii) Terminalisation of chiasmata
(iv) Disappearance of nucleolus

(a) (ii), (i), (iv), (iii) (b) (ii), (i), (iii), (iv)
(c) (i), (ii), (iii), (iv) (d) (ii), (iii), (iv), (i) *(Re-AIMPT 2015)*

84. The number of chromosomes in meiocyte (2N) of apple is:
(a) 24 (b) 380 (c) 34 (d) 20 *(KCET 2015)*

85. Some cells in adult animals do not divide. They exit no G_1 phase and enter in an inactive stage called:
(a) G_2 phase (b)G_0 phase (c) S-phase (d) M-phase *(KCET 2015)*

86. Which one of the following is the significance of mitosis?
(a) Restricted to haploid cells (b) Cell repair
(c) Increases genetic variability (d) Recombination of chromosomes
(e) Leads to evolution of new genotype *(Kerala PMT 2015)*

87. In a typical eukaryotic cell cycle, Gap-I synthesis and Gap-2 are those phases included in the:
(a) Prophase (b) Metaphase (c) Anaphase (d) Interphase (e) Telophase
(Kerala PMT 2015)

88. Find the correct statement:
(a) During mitosis, Endoplasmic reticulum and nucleolus disappear at early prophase
(b) Chromosome is made up of 2 sister chromatids at anaphase of mitosis.
(c) Chromosomes are arranged along the equator during prophase of mitosis
(d) A cell plate is laid down during interphase
(e) Small disc-like structures at the surface of centromeres that appear during metaphase are kinetochores
(Kerala PMT 2015)

89. During cell growth, DNA synthesis occurs in:
(a) M-phase (b) S-phase (c) G_1-phase (d) G_2-phase *(NEET {Phase-II} 2016)*

90. Mechanism that causes a gene to move from one linkage group to another is called:
(a) Crossing over (b) Inversion (c) Duplication (d) Translocation *(NEET {Phase-II} 2016)*

91. When cell has stalled DNA replication, which check point should be predominately activated?
(a) Both G_2/M and M (b) G_1/S (c) G_2/M (d) M *(NEET {Phase-II} 2016)*

92. Match the stages of meiosis in column-I to their characteristic features in column-II and select the correct option using codes given below:

	Column-I	Column-II
1.	Pachytene	(i) Pairing of homologous chromosomes
2.	Metaphase-I	(ii) Terminalization of chiasmata
3.	Diakinesis	(iii) Crossing over takes phase
4.	Zygotene	(iv) Chromosomes align at equatorial plate

1	2	3	4
(a) (iv)	(iii)	(ii)	(i)
(b) (iii)	(iv)	(ii)	(i)
(c) (i)	(iv)	(ii)	(iii)
(c) (ii)	(iv)	(iii)	(i)

(NEET {Phase-II} 2016)

93. In meiosis, crossing over is initiated at:
(a) Diplotene (b) Pachytene (c) Leptotene (d) Zygotene *(NEET {Phase-I} 2016)*

94. Which of the following is not a characteristic feature during mitosis in the somatic cells?:
(a) Synapsis (b) Spindle fibres (c) Disappearance of nucleolus
(d) Chromosome movement *(NEET {Phase-I} 2016)*

95. Spindle fibres attach on to:
(a) Kinetosome of the chromosome (b) Telomere of the chromosome
(c) Kinetochore of the chromosome (d) Centromere of the chromosome *(NEET {Phase-I} 2016)*

96. A cell at telophase stage is observed by a student in a plant brought from the field. He tells his teacher that this cell is not like other cells at telophase stage. There is no formation of cell plate and the cell is containing more number of chromosomes as compared to other dividing cells. This would result in:
(a) Polyteny (b) Aneuploidy (c) Polyploidy (d) Somaclonal variations *(NEET {Phase-I} 2016)*

97. Which of the following options gives the correct sequence of events during meiosis ?
(a) Condensation → Nuclear membrane disassembly → Crossing over → Segregation → Telophase
(b) Condensation → Nuclear membrane disassembly → Arrangement at equator → Centromere division → Segregation → Telophase
(c) Condensation → Crossing over → Nuclear membrane disassembly → Segregation → Telophase
(d) Condensation → Arrangement at equator → Centromere division → Segregation → Telophase *(NEET 2017)*

98. Zygotic meiosis is characteristic of:
(a) *Marchantia* (b) *Fucus* (c) *Funaria* (d) *Chlamydomonas* ***(NEET 2017)***

99. Anaphase Promoting Complex (APC) is a protein-degradation machinery necessary for proper mitosis of animal cells. If APC is defective in a human cell, which of the following is expected to occur ?
(a) Chromosomes will not condense (b) Chromosomes will be fragmented
(c) Chromosomes will not segregate (d) Recombination of chromosome arms will occur ***(NEET 2017)***

100. The stage during which separation of paired homologous chromosomes begins is:
(a) Pachytene (b) Diakinesis (c) Diplotene (d) Zygotene ***(NEET 2018)***

ANSWERS

1. (a);	**2.** (b);	**3.** (b);	**4.** (a);	**5.** (c);	**6.** (d);	**7.** (d);	**8.** (e);	**9.** (a);	**10.** (a);
11. (b);	**12.** (a);	**13.** (b);	**14.** (d);	**15.** (b);	**16.** (d);	**17.** (c);	**18.** (c);	**19.** (a);	**20.** (b);
21. (b);	**22.** (a);	**23.** (c);	**24.** (b);	**25.** (a);	**26.** (a);	**27.** (c);	**28.** (a);	**29.** (d);	**30.** (b);
31. (a);	**32.** (d);	**33.** (c);	**34.** (d);	**35.** (c);	**36.** (a);	**37.** (c);	**38.** (b);	**39.** (a);	**40.** (c);
41. (a);	**42.** (d);	**43.** (b);	**44.** (b);	**45.** (c);	**46.** (a);	**47.** (d);	**48.** (d);	**49.** (c);	**50.** (c);
51. (c);	**52.** (e);	**53.** (c);	**54.** (c)	**55.** (a);	**56.** (d);	**57.** (a);	**58.** (d);	**59.** (c);	**60.** (c);
61. (a);	**62.** (a);	**63.** (a);	**64.** (a);	**65.** (d);	**66.** (a);	**67.** (c);	**68.** (d);	**69.** (a);	**70.** (b);
71. (c);	**72.** (b).	**73.** (c);	**74.** (a);	**75.** (a);	**76.** (d);	**77.** (a);	**78.** (c);	**79.** (c);	**80.** (d).
81. (b);	**82.** (c);	**83.** (b);	**84.** (c);	**85.** (b);	**86.** (b);	**87.** (d);	**88.** (e);	**89.** (b);	**90.** (d);
91. (c);	**92.** (b);	**93.** (b);	**94.** (a);	**95.** (c);	**96.** (c);	**97.** (c);	**98.** (d);	**99.** (c);	**100.** (c).

HINTS OF SOME DIFFICULT MULTIPLE CHOICE QUESTIONS

4. (a) : As at metaphase, the chromosomes are maximally condensed and morphologically most distinct.

15. (b) : As the prophase-I of meiosis is formed of 5 subphase; Leptotene, Zygotene, Pachytene, Diplotene and Diakinesis. Synapsis occurs during zygotene of Prophase-I of meiosis.

33. (c) : D represents S-phase of interphase in which DNA replication and biosynthesis of histones occur. A is Karyokinesis; B is Anaphase and C-is Cytokinesis.

48 (d) : Diplotene follows the pachytene. As the crossing over has taken place and the homologous chromosomes are to be separated so the synaptonemal complex dissolves in diplotene.

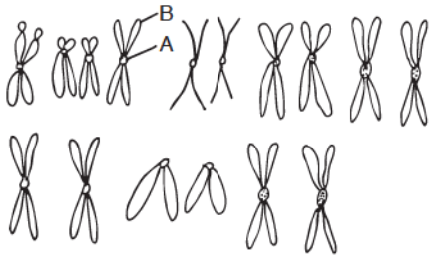
62. (a) : Spindle fibres are formed by polymerization of dimeric tubulin molecules. Colchicine causes depolymerization of microtubules so inhibits spindle formation.

67. (c) : Root cells are diploid (2N = 14) so the haploid number is 7. Synergid cells of embryo sac of ovule are haploids so have 7 chromosome number.

90. (d) : Crossing over is exchange of genes between non-sister chromatids of homologous chromosomes (i.e. same linkage group) while translocation involves transfer of genes from a chromosome to a non-homologous chromosome (i.e. chromosome of other linkage group).

B. CBSE - PMT (MAIN EXAMINATION) QUESTIONS :

1. Answer the following questions based upon the given figure :
(a) What type of division is this? Whether meiotic or/and mitotic and which stage?
(b) What is A and B?



(c) Does it represent human chromosomes? Explain.
(d) What is acrocentric chromosome? How many acrocentric chromosomes present in the given diagram? (*CBSE 2006*)

Ans. (a) It is a **meiotic division** showing synapsis and it is in the zygotene stage of prophase – I of meiosis – I.
(b) A = Centromere, B = Chromatid.
(c) No, it does not represent the human chromosomes, because :
– humans have 23 pairs of chromosomes and it is less than 23 pairs in the given figure.
– human lacks telocentric chromosomes (where centromere is present at terminal end) which is given in the figure.
(d) An **acrocentric chromosome** is one in which the centromere is located very near to one of the ends of the chromosome, thus giving the chromosome a short arm and a long arm. The "acro-" in acrocentric refers to the Greek word for "end." In the given figure there are **two pairs to acrocentric chromosomes.**

2. **Fill in the blank :**
The centriole forms spindle during cell division in ..... cells. (*CBSE 2008*)

Ans. Animal.

3. **At metaphase, chromosomes are attached to the spindle fibres by their :**
(a) Kinetochores (b) Centromeres (c) Satellites (d) Secondary constrictions (*CBSE 2011*)

Ans. (a).

4. **Identify the meiotic stage in which the homologous chromosomes separate while the sister chromatids remain associated at the centromeres:**
(a) Metaphase-I (b) Metaphase-II (c) Anaphase-I (d) Anaphase-II (*CBSE 2012*)

C. MATCHING TYPE QUESTIONS :

Match the terms in Column A with suitable terms in Coulmn B :

Column A	Column B
(i) Cell plate	(a) Carcinogen
(ii) Polyploidy	(b) Anaphase - I
(iii) Cancerous tumour	(c) Mitosis
(iv) Double replication forks	(d) Zygotene
(v) Disjunction	(e) Phragmoplasts
(vi) Synapsis	(f) Meiosis
(vii) Plectonemic coiling	(g) Colchicine
(viii) Bouquet stage	(h) Prokaryotic chromosome

(*KCET 2012*)

ANSWERS

1. (i) (e); (ii) (g); (iii) (a); (iv) (h); (v) (b); (vi) (d); (vii) (c); (viii) (f).

D. ASSERTION TYPE QUESTIONS :

The following questions consist of two statements each : Printed as *Assertion* and *Reason*. While answering these questions, you are required to choose any one of the following four responses :

A. If both *Assertion* and *Reason* are true and *Reason* is the correct explanation of *Assertion*.
B. If both *Assertion* and *Reason* are true but *Reason* is not the correct explanation of *Assertion*.
C. If *Assertion* is true but *Reason* is false.
D. If both *Assertion* and *Reason* are false.

1. **Assertion :** Synapsis is involved pairing of homologous chromosomes during zygotene of meiosis.
Reason : Crossing over produces variations in the cells.
A B C D (*AIIMS 1996*)

2. **Assertion**: Daughter cell produced by meiosis are haploid.
Reason: In meiosis, there is no DNA replication between meiosis-I and meiosis-II.
A B C D (*AIIMS 1996*)

3. **Assertion**: Chromosomal congression leads to equatorial arrangement of chromosomes during metaphase.
Reason : Force responsible for equatorial arrangement of chromosomes is equal pull of chromosomal fibres.
A B C D (*AIIMS 1997*)

4. **Assertion**: Reduction of chromosome number occurs during anaphase-I
Reason: Non-disjunction occurs during anaphase-I.
A B C D (*AIIMS 1997*)

5. **Assertion**: Karyotypic analysis is scientific study of complete chromosome complement of an individual.
Reason: Karyotypic analysis can be used to diagnose the pre-natal chromosomal disorders.
A B C D (*AIIMS 1998*)

6. **Assertion :** Meiotic division results in the production of four dissimilar cells.
Reason : Synapsis occurs during zygotic meiosis.
A B C D (*AIIMS 1998*)

7. **Assertion :** Old age is not an illness. It is a continuation of life with decreasing capacity for adaptation.
Reason : Cessation of mitosis is a normal genetically programmed event.
A B C D (*AIIMS 2003*)

8. **Assertion :** Among the primates, the chimpanzee is the closest relative of the present day humans.
Reason : The banding pattern in the autosome numbers 3 and 6 of man and chimpanzee is remarkable similar.
A **B** **C** **D** (*AIIMS 2004*)

9. **Assertion :** Phase of cell division is also known as formative phase.
Reason : In formative phase, new cells are produced from pre-existing cells through mitosis division.
A **B** **C** **D** (*AIIMS 2007*)

10. **Assertion :** Reduction division occurs in Anaphase–I.
Reason : Meiosis–II occurs to separate homologous chromosomes.
A **B** **C** **D** (*AIIMS 2009*)

ANSWERS

1. B;	2. A;	3. A;	4. C;	5. B;	6. B;	7. A;	8. A;	9. C;	10. C.

E. ADDITIONAL MULTIPLE CHOICE QUESTIONS :

Choose the correct answer :

1. At what stage of cell cycle are histone proteins synthesized in a eukaryotic cell?
(a) During entire prophase (b) During telophase (c) During S-phase (d) During G_2-phase
2. Centromere is required for :
(a) Transcription (b) Crossing over
(c) Cytoplasmic cleavage (d) Movement of chromosomes towards poles
3. In meiosis, the daughter cells are not similar to that of parent because of :
(a) Crossing over (b) Synapsis (c) Both (a) and (b) (d) None of these
4. When synapsis is complete all along the chromosome, the cell is said to have entered a stage :
(a) Zygotene (b) Pachytene (c) Diplotene (d) Diakinesis
5. Meiotic crossing over involves :
(a) Non-sister chromatids of a pair of homologous chromosomes
(b) Sister chromatids
(c) Chromatids of non-homologous chromosomes
(d) None of the above
6. Synthesis of RNA and proteins takes place in :
(a) M-phase (b) S-phase (c) G_1-phase (d) G_1 and G_2-phases
7. During the meiotic division, the :
(a) Homologous chromosomes are separated (b) Homologous chromosomes do not segregate
(c) The linkage is disturbed (d) All of the above
8. If a cell has twice as much DNA as in a normal functional cell, it means that the cell :
(a) Is preparing to divide (b) Has completed division
(c) Has reached the end of life span (d) Has ceased to function
9. During cell division, chromosome attaches with spindles at :
(a) Kinetochore (b) Centromere (c) Centriole (d) Secondary constriction
10. Cyclin protein is required for cell cycle, which other molecule is essential for completion of cell cycle?
(a) CCK (b) CKc (c) CdK (d) CKd
11. When does synapsis occur in meiosis?
(a) Zygotene (b) Leptotene (c) Diplotene (d) Pachytene
12. Astral rays arise from :
(a) Centriole (b) Cytoplasm (c) Chromatid (d) Centromere
13. Meiotic division is also called reductional division because :
(a) A gamete becomes involved (b) Number of chromosomes becomes halved
(c) Number of chromosomes becomes doubled (d) Chromosomes are eliminated
14. A diploid living organism develops from zygote undergoes which type of repeated cell division?
(a) Meiosis (b) Amitosis (c) Mitosis (d) Segmentation
15. Synaptinemal complex is observed during cell division in :
(a) Meiotic prophase (b) Mitotic prophase (c) Meiotic metaphase (d) Mitotic telophase

16. Zygotic meiosis occurs in :
(a) *Dryopteris* (b) *Marchantia* (c) *Pinus* (d) *Chlamydomonas*

17. During G_1 phase of cell division :
(a) RNA and proteins are synthesized (b) DNA and proteins are synthesized
(c) Cell prepares for cell division (d) Cell undergoes duplication

18. In cell cycle, during which phase chromosomes are arranged at equatorial plate?
(a) Metaphase (b) Anaphase (c) Telophase (d) Prophase

19. Spindle fibres are made up of :
(a) Tubulin (b) Humulin
(c) Intermediate filaments (d) Flagellin

20. The drug colchicine has inhibitory effect on cell cycle in which stage?
(a) G_1 (b) S (c) M (d) G_2

21. Type of sexual reproduction in protists, bearing diploid chromosome is :
(a) Zygotic meiosis (b) Binary fission (c) Cyst formation (d) Gametangial meiosis

22. Number of mitotic divisions required for the formation of 128 cells :
(a) 127 (b) 32 (c) 12 (d) 7

23. Chromosomes are separated during :
(a) Prophase (b) Metaphase (c) Anaphase (d) Telophase

24. In cell cycle, DNA replication occurs during :
(a) G_1 phase (b) G_2 phase (c) Metaphase
(d) Anaphase (e) S-phase

25. At what stage of the cell cycle, the histone proteins are synthesized in a eukaryotic cell?
(a) During entire prophase (b) During telophase (c) During S-phase (d) During G_2-phase

26. Replication of centriole occurs during :
(a) Interphase (b) Prophase (c) Early telophase (d) Late telophase

27. L-shaped chromosomes are also called :
(a) Acrocentric (b) Telocentric (c) Sub-metacentric (d) None of these

28. A gymnospermic leaf contains 16 chromosomes. The number of chromosomes in its endosperm is :
(a) 24 (b) 16 (c) 12 (d) 8

29. Colchicine arrests which of the following stage of cell division?
(a) Prophase (b) Metaphase (c) Anaphase (d) Telophase

30. Characteristic of meiosis is :
(a) Two nuclear and two chromosome divisions (b) Two nuclear and one chromosome division
(c) One nuclear and two chromosome divisions (d) One nuclear and one chromosome division

ANSWERS

1. (c);	**2.** (d);	**3.** (a);	**4.** (b);	**5.** (a);	**6.** (d);	**7.** (a);	**8.** (a);	**9.** (a);	**10.** (c);
11. (a);	**12.** (a);	**13.** (b);	**14.** (c);	**15.** (a);	**16.** (d);	**17.** (a);	**18.** (a);	**19.** (a);	**20.** (c);
21. (d);	**22.** (d);	**23.** (c);	**24.** (e);	**25.** (c);	**26.** (a);	**27.** (c);	**28.** (d);	**29.** (b);	**30.** (b).

Chapter Practice Test

Time Allowed : 1 : 30 Hours *Maximum Marks : 35*

1. Why is interphase also called preparatory phase ? (1)
2. What is peculiar about G_0 phase? (1)
3. Define crossing over. (1)
4. Which cell division keeps genetic homogeneity? (1)
5. What is kinetochore? Give its significance. (1)
6. Enlist the peculiar events which occur during S-phase and G_2-phase of interphase. (2)
7. Define synaptinemal complex. Give its significance. (2)
8. State two benefits of mitosis. (2)
9. Give the composition of mitotic apparatus. (2)
10. Differentiate between Metaphase of mitosis and Metaphase-I of meiosis. (2)
11. List the event which occurs during following stages: (3)
    (i) Zygotene (ii) Pachytene (iii) Anaphase-I
12. Enlist the significane of meiosis. (3)
13. Describe the prophase of mitosis. (3)
14. List the stages during which following events occur: (3)
    (i) Desynapsis (ii) Disappearance of synaptinemal complex
    (iii) Reduction of amount of DNA per chromosome
15. Write notes on: (3)
    (i) Metaphase plate (ii) Control of mitosis.
16. Enumerate prophase-I of meiosis with labelled diagrams. (5)

❑❑❑

To check your performance, see ANSWERS TO CHAPTER PRACTICE TEST at the end of Part I of the book.

ANSWERS TO CHAPTER PRACTICE TESTS

CHAPTER 1 : THE LIVING WORLD

1. Monograph is an exhaustive treatment of a single taxon dealing with identification, nomenclature and classification of its members.
2. A pair of alternate characters.
3. **Odd one** : (i) Taxon (ii) *indica* (iii) *Eucalyptus*
4. (i) Phylum (ii) Order (iii) Phylum
5. Species
6. It is the occurrence of different forms of life with different modes of nutrition, living in varied habitats.
7. **Largest botanical garden** : Royal Botanical Garden, Kew (London).
   Well known botanical gardens in India :
   (i) National Botanical Garden, Lucknow (ii) Lloyd Botanical Garden, Darjeeling
8. (i) It provides information about the relationship of an arganism.
   (ii) It helps in easy and quick identification of a taxon.
9. (i) Reproduction (ii) Growth and Metabolism (iii) Consciousness
10. When anabolism exceeds catabolism, growth appears.
11. **Family** : for plants-aceae; for animals - ideae.
    Order : for plants - ales; for animals - not fixed.
    e.g. carnivora, primata
    Class : for plants - opsida, - phyceae and - ae
    for animals - ia e.g. mammalia
12. Refer Ans. 2 'NCERT File', Exercise questions.
13. Refer Table 5 of this Chapter.
14. Refer 'Disadvantages of common vernacular names' in 'Binomial nomenclature' of this Chapter.
15. Refer Answer 14 of 'Practice problems - Wild life.'
16. Refer 'Systematic taxonomy' and 'classification guidelines' of this Chapter.

CHAPTER 2 : BIOLOGICAL CLASSIFICATION

1. Chemosynthetic bacteria are autotrophic as they can form the food with the help of energy obtained from chemical reactions from simple raw material.
2. Because, they bear enzymes for metabolisation of both cellulose and lignin.
3. Dolipore is the barrel shaped outgrowth present in septum of basidiomycetes.
4. Bracket fungi are lignocolous which produce bracket or shelf shaped hard leathery basidiocarp which comes out of tree trunk e.g. *Fomes tomentarius.*
5. *Euglena*, Dinoflagellates, Zooflagellates.
6. (i) Unicellular, flagellum with basal granules
   (ii) Well developed nucleus.
7. Diatoms and desmids are included in chrysophytes. They are both marine and freshwater and are major phytoplanktons.
8. Capsid is a proteinaceous covering around virus. It takes part in protection of nucleoid from damage.
9. *Trichoderma.* It is a soil fungus and used in biological control of other fungi. It produces allelochemicals against them. It produces leukopenia (alimentary canal aleukia) in human alimentary canal.
10. (a) **Early blight** : *Alternaria solani*
    (b) **Red rot of sugarcane** : *Colletotrichum falcatum*
    (c) **Wilt** : *Fusarium oxysporium*
    (d) **Brown leaf spot of rice** : *Helminthosporium oryzae*

11. Refer 'Structure of some important viruses' of this Chapter.
12. Refer 'Reproduction' in 'Kingdom Fungi' of this Chapter.
13. Refer Answer-1 of 'NCERT File' in 'NCERT Exercise Questions' of this Chapter.
14. Refer 'Modern taxonomy/New systematics' of this Chapter.
15. Refer Table - 5 of this Chapter.
16. Refer 'Viruses, viroids and bacteriophages' of this Chapter.

CHAPTER 3 : PLANT KINGDOM

1. When gametophytic and sporophytic generations in an organism follow each other in a regular fashion, it is called as **alternation of generations.**
2. **Elaters** are hygroscopic structures present in capsule of sprogonium. They help in release of spores by twisting movements like spring of a watch.
3. Dichotomously branched veins without anastomosis venation i.e. **furcate type of venation.**
4. In Cycas, sperms are multiflagellate, while in other seed plants they are non-flagellate.
5. Protonema is filamentous, juvenile, autotrophic and gametophytic stage exhibited by mosses.
6. **Haplodiplontic** : *Dictyota, Ulva*

   Diplontic: *Fucus, Cladophora*
7. Ferns bind the soil and provide cover to the soil on hill slopes. They help in checking of soil erosion. In secondary succession, ferns are one of the early colonizers.
8. Peat mosses like *Sphagnum* grow very fast in shallow waters. They form thick mats on water surface. They impart appearance of false soil and may lead to drowning of animals.
9. Bryophytes, Pteridophytes and Gymnosperms
10. **(i) Zygote**: Diploid **(ii) Ovum**: Haploid

    (iii) Gemma : Haploid **(iv) Prothallus**: Haploid.
11. Refer Table 1 of this Chapter.
12. Refer Q. 7 of 'NCERT Exercise Questions' in 'NCERT File'.
13. Refer 'Haplo-diplontic life cycle' in 'Plant Cycles and Alternation of Generations' in this Chapter.
14. Seeds are exposed or naked in gymnosperms. Seeds are covered in angiosperms. Process of double fertilization is present in angiosperms. Angiosperms produce flowers. In gymnosperms seeds are borne in structures called cones. In angiosperms ovary ripens in fruit, which contains seeds.
15. Refer 'Cytotaxonomy' and 'Chemotaxonomy' of 'Phenetic classification' of this Chapter.
16. Refer 'Methods of asexual reproduction' in 'Algae' of this Chapter.

CHAPTER 4 : ANIMAL KINGDOM

1. **Tissue** organization.
2. When external division of body corresponds with internal division of coelom, it is called **metameric segmentation**. It is found in **Annelida**.
3. Viviparity and placenta formation.
4. Presence of sclerotised exoskeleton.
5. When an advanced larva changes into a degenerate adult by loss of certain characters it is called retrogressive metamorphosis. It is found in ***Herdmania.***
6. (i) Presence of pores like dermal ostia and osculum on body surface.
   (ii) Presence of canal system.
   (iii) Presence of choanocytes (collar cells) in gastral layer of body wall.
   (iv) Diploblastic animals with cellular organization.
   e.g. Sycon, Euplectella.
7. Refer Table 11 of chapter – 4
8. A false body cavity, called pseudocoel, filled with blood is called **haemocoel**.
   It is found in arthropods and molluscs.
9. *Petromyzon* belongs to class **Cyclostomata** of Gnathostomata. It is characterized by :
   (i) Presence of **circular mouth** bounded by **suctorial funnel** with horny teeth.

(ii) Paired fins are absent but median fins are present.
(iii) Skin is without scales and is monorhinus.

10. Duck billed platypus belongs to class **Mammalia**. It acts as a **connecting link** between **Reptilia** (lays yolky and shelled eggs, possesses large sized coracoids and cloacal aperture) and **Mammalia** (presence of hair and mammary glands) .

11. (i) Presence of feathery exoskeleton.
(ii) Fore limbs are modified into wings.
(iii) Stream-lined body to reduce air resistance in flight.
(iv) Mouth is bounded by beak.
(v) Preumaticity in the bones.
(vi) 4-chambered heart and homeothermy.
Examples : *Struthio* (ostrich), *Pavo* (Peafowl) and *Columba* (Pigeon).

12. Coelom is body cavity between parietal peritoneum of body wall and visceral peritoneum.
- Poriferans to flatworms are without coelom and are called **acoelomates** .
- Round worms have false body cavity (called **psuedocoel**) so are called **pseudocoelomates**.
- Annelids to mammals are **eucoelomates** as these have true coelom.
- In Arthropods and molluscs, a blood-filled haemocoel is present so are called **haemocoelomates**.

13. Refer Table – 3 of chapter – 4 .

14. (i) Presence of **notochord** on dorsal side between gut and nerve cord.
(ii) Dorsal and hollow **central nervous system**.
(iii) Presence of **gill slits** on lateral side of pharynx.
(iv) Presence of tail.

15. (i) Body divided into three body parts: Head, foot and visceral mass.
(ii) Presence of **mantle** or **pallium** (a glandular fold).
(iii) Body generally enclosed in a **shell**.
(iv) Open-type circulatory system while blood is **blue-coloured** due to **haemocyanin** pigment.
(v) Presence of a chemosensory organ called **ospharidium**.
(vi) Respiration occurs either with gill or pulmonary sac.
Eaamples : *Pila* (Apple snail) ; *Sepia* (Cattle fish) and *Unio*.

16. (i) Due to presence of homeothermy, four optic lobes, coiled cochlea, power of learning and speech, viviparity, placentation and parental care.
(ii) In birds, fore limbs are modified into wings and body is streamlined. Body is light due to presence of pneumaticity in the bones and absence of urinary bladder, and teeth.
(iv) Protochordates (e.g. *Herdmania* and *Amphioxus*) are chordates due to presence of notochord but do not have vertebral column so are not vertebrates.

CHAPTER 5 : MORPHOLOGY OF FLOWERING PLANTS

1. **Sucking roots** are haustorial roots of parasites which pass into the host plant for obtaining nourishment e.g. *Cuscuta*.

2. **Sympodial axis** is a compound axis formed by fusion of a part of main axis and the bases of successive lateral branches in uniparous cymose branching e.g. *Saraca indica*.

3. Foliage leaves, scale leaves, bracts, bracteoles, cotyledons, prophylls and floral leaves.

4. **Spikelet** is a small compact, few flowered spike which is enclosed by two scales called glumes.

5. **Nut** is a single seeded dry indehiscent fruit having a hard woody or leathery covering e.g. Litchi.

6. In this case, opposite leaves of successive nodes lie at right angles thus form four rows e.g. *Ocimum*, *Calotropis*.

7. **Replum** is a false septum which develops in between two parietal placentae. It is found in family Cruciferae.

8. **Palmate leaf** is a leaf bearing number of principal veins, if **simple** and all leaflets attached directly to the tip of petiole, if **compound**.

9. **Umbel** is a simple racemose inflorescence in which pedicellate flowers are borne radially from a single point due to reduction in the size of peduncle e.g. *Centella*.

10. Phylloclades are green modified stem and are able to do photosynthesis. The leaves are drought deciduous or caducous. They become fleshy and are with unlimited growth e.g. *Opuntia*, *Euphorbia royleana*.

-11. Refer Fig. 78 of this chapter.

12. Refer 'Economic importance' in family 'Solanaceae' of this chapter.

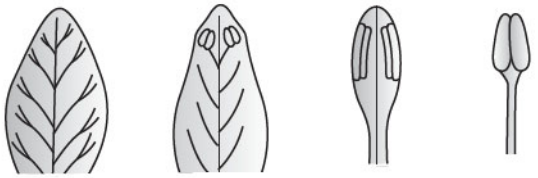
13. Refer 'Structure of maize grain' of this chapter.

14. Refer 'Table 18' of this chapter.
15. Few evidences which prove that 'flower is a modified shoot' are:

(i) A flower appears from a bud.

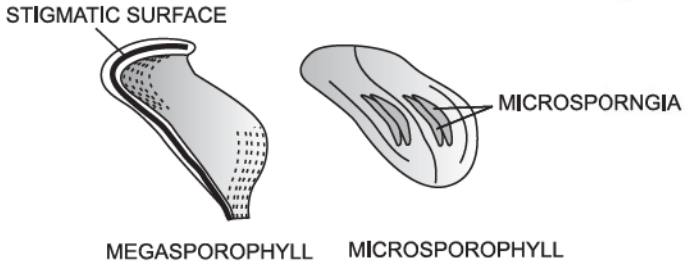
(ii) In rose, tip of flower can elongate to form another flower or vegetative shoot.

(iii) In *Nymphaea* (water lily), transitional stages between sepals and petals and also in petals and stamens can be observed.



Transitional stages from petal to stamen in *Nymphaea*.

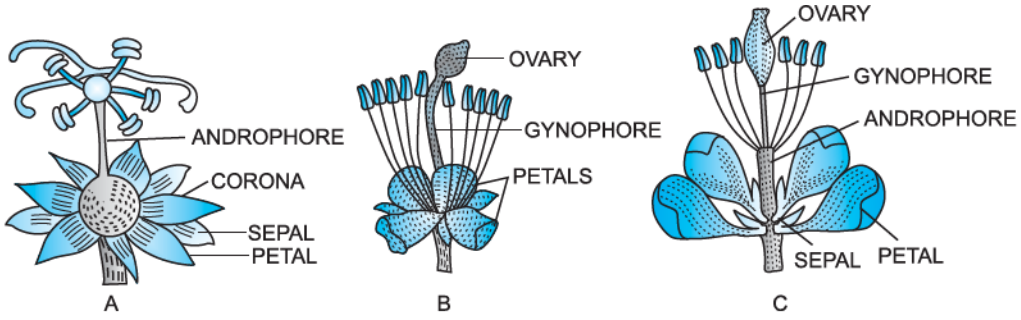
(iv) In *Degenaria*, carpels donot bear style and stigma. Carpel is represented by folded leaves.



Sex organs in Degenaria

(v) Sepals look like vegetative leaves in rose.

(vi) Presence of **androphore** in *Passiflora* and **gynophore** in *Capparis* and both androphore and gynophore *Gynandropsis* indicates its vegetative shoot like characters.



A; Androphore of *Passiflora*, B; Gynophore of *Capparis*; C, Both androphore and gynophore in Gynandropsis.

16. Refer 'Regions of typical root' and Fig. 3 of this chapter.

CHAPTER 6 : ANATOMY OF FLOWERING PLANTS

1. Because it is found parallel to circumference and helps in increase in girth.
2. (i) Companion cell controls the functioning of sieve tube element.

   (ii) It maintains pressure gradient in the sieve tube.
3. It is first formed formed xylem and is made up of narrow, smaller elements.
4. Calyptrogen in a distinct histogen formed in monocot roots and it forms root cap.
5. Bulliform or motor cells.
6. (i) It takes part in the conduction of water from root hair to the inner tissue.

   (ii) Storage of food.

   (iii) In older roots, it produces protective exodermis.
7. Secondary phloem is formed from lateral meristem known as vascular cambium. It is found in plants showing secondary growth like dicots and gymnosperms.
8. Because, endodermis in dicot stem is rich in starch grains.

9. The cells of medullary rays become meristematic and form the **interfascicular cambium.** Cells of cambium present between primary xylem and primary phloem is called **intrafascicular cambium.** Both these types of combia from a ring of combia.
10. (i) To provide mechanical strength (ii) It bears spaces for gaseous exchanges (iii) To carry photosynthesis.
11. Refer Table 12 of this chapter.
12. Refer Table 17 of this chapter.
13. Refer 'History of Young dicot root' of this chapter.
14. Refer 'Sap wood and heart wood' of this chapter.
15. Refer 'Xylem' of this chapter.
16. Refer 'Importance of studying anatomy' of this chapter.

CHAPTER 7 : STRUCTURAL ORGANISATION IN ANIMALS

1. For easy exchange of gases at the alveoli.
2. Presence of intercalated discs and oblique bridges.
3. Fibrocartilage (white fibrous cartilage).
4. Clitellum is a glandular band around 14,15 and 16 segments of earthworm. It secretes ootheca.
5. Vocal sacs are balloon-like distensible structures present on the throat of male frog. These amplify the croaking sound.
6. Refer Table 5 of chapter 7.
7. (i) **Fibroblasts** secrete the collagen and elastin protein fibres.
   (ii) **Histiocytes** act as phagocytes and engulf microbes and dead cells.
   (iii) **Mast cells** secrete matrix, heparin and serotonin.
   (iv) **Plasma cells** secretes antibodies.
8. Refer Table 23 of chapter 7.
9. **Typhlosole** is a large sized fold hanging in lumen of middle part of intestine in earthworm. It increases surface area for digestion and absorption of food.
10. Refer Table 32 of chapter 7.
11. Refer Fig. 22-D chapter 7.
12. Refer Table 18 of chapter 7.
13. (i) Plasma of blood transports nutrients, oxygen, carbon- dioxide, metabolic wastes and hormones inside the body.
    (ii) Prothrombin and fibrinogen proteins help in blood clotting at injury.
    (iii) γ-globulin proteins of plasma act as antibodies and provide immunity.
    (iv) Albumins of plasma help in osmotic balance of blood.
    (v) Sodium bicarbonate and certain proteins help in pH- consistency.
14. Each compound eye of cockroach is formed of large number of visual units called **ommatidia**. Each ommatidium is formed of light-focussing **dioptric part** and a photosensitive part called **receptive** part having retinulae. Each ommatidium forms the image of a part of object so the final image is formed of a number of small images lying side by side. This is called **mosaic vision.**
15. Heart of frog is surrounded and protected by **pericardium**. It is **3-chambered** and is formed of two completely separated **auricles** and one unpartitioned **ventricle**. Two auricles are separated by a thin interauricular septum. There are also two accessory chambers: **Sinus venosus** receives deoxygenated blood from body parts and opens in right auricle; and a tubular **truncus arteriosus** which divides into 2 aortic trunks each of which divides and forms 3 arches.
16. **(a)** Refer Fig. 44 of chapter 7
    (b) Nissl's granules are electron microscopic basophilic granules present in the neuroplasm of the cell body. These are rich in RER and are sites of protein synthesis.
    (c) A synapse is close position of synaptic knob of axon of one neuron and dendron of next neuron.

CHAPTER 8 : CELL : THE UNIT OF LIFE

1. Cell theory was proposed by **Schleiden and Schwann** (1839). The objectionable postulate of cell theory was that the new cells are formed *de novo* (afresh from non-living materials).
2. Smallest-sized cell = *Mycoplasma.*
   Largest sized plant cell = *Acetabularia*
3. Movement of molecules (or materials) from higher concentration to lower concentration (i.e. diffusion) in the presence of certain carrier molecules (called **permeases**) is called **facilitated diffusion.**
4. Cell organelles are living cytoplasmic structures, while cell inclusions are non-living cytoplasmic structures.
5. (i) Cell sap of plant vacuole exerts turgor pressure which helps in growth of young plant cell.
   (ii) It stores water,nutrients, minerals and wastes.
6. Nucleoid of prokaryotic cells is characterized by:
   (i) Abscence of nuclear membrane, nuclear sap and nucleolus.
   (ii) Contains single and circular chromosome formed of only double-stranded DNA but not associated with histones.
7. Refer Table 7 of chapter-8
8. (i) Acts as **cell-circulatory system** and helps in transportation of materials inside the cell.
   (ii) Forms a **part of cytoskeleton** so provide mechanical support and shape to the cell.
   (iii) SER involved in biosynthesis of lipids, steroid hormones, etc.
   (iv) RER involved in protein synthesis.
9. Because the lysosomes contain acid hydrolases enzymes in inactive form which, on cellular death, are released for self-digestion of cell.
10. Refer Table 16 of chaper-8.
11. Main postulates of Fluid-mosaic model are:
    (i) Plasma membrane is lipoproteinous and trilaminar.
    (ii) Phospholipid molecules form a middle bilayer and show transition as well as flip-flop movements. These are amphipathic in nature.
    (iii) Proteins are globular-shaped and are of 2 types: extrinsic and intrinsic proteins.
    (iv) Carboydrates lie on only outer surface of membrane and are associated with lipids or protein to form glycolipids and glycoproteins respectively.
    Refer Fig. 12 of chapter-8
12. **Mitochondrion : Refer Fig. 30 of chapter-8**
    These are called **semiautonomous** as can form some required proteins on their own due to presence of DNA, m-RNA, ATP molelcules and 70 S ribosome. But for some other proteins, these depend upon nuclear DNA and cytoplasmic 80 S ribosomes.
13. A nucleolus is naked structure present in the nucleoplasm. It is formed of 4 parts : central and proteinous **pars amorpha, fibrillar zone** and **granular zone** formd of RNA fibrils and nucleolus-**associated chromatin** formed of nucleolar DNA.
    Functions: Nucleolus is site of biosynthesis and storage of r-RNA.
    Refer Fig. 40 of chapter-8
14. **Centriole : Refer Fig. 33 A of chapter-8**
    Functions: Centrioles **form aster** during cell divison of animal cells, form basal bodies and axial filament of flagellum of sperm.
15. **Refer Table 14 of chapter-8**
16. **(a) Refer Fig. 32 of Chapter-8**
    (b) Because each thylakoid has small rounded particles, called **quantasomes,** along inner surface of its membrane. Each quantasome contains pigments like chlorophylls, carotenoids, plastoquinone, plastocyanin, etc. which are inovled in photosynthesis.

CHAPTER 9 : BIOMOLECULES

1. 100
2. Glycogen, Starch.
3. Cellulose is a long chain of branched linear polymer of several glucose units attached by β (1→4) linkages. It constitutes structural polysaccharide of plant cell walls.
4. Purine is nine membered double cyclic nitrogen base bearing nitrogen at 1, 3, 7 and 9 positions e.g. adenine (A) and guanine (G).

5. Fat is a type of simple lipid. It is also known as triglyceride because it is made-up by estirification of three fatty acids with trihydric alcohol i.e. glycerol.
6. Waxes are chemically inert esters' of long chain fatty acids with monohydric alcohol like oleyl, cetyl, myricyl e.g. lanolin, bees wax, paraffin wax.
7. Uracil (U). It is present in RNA in viruses like hepatitis C.
8. Triose, fructose, maltose, oligosaccharide, starch.
9. Enzymes, antibodies, haemoglobin, and adrenaline receptors all are proteins. Hence they are called as biological polymers.
10. Enzyme becomes temporarily inactive at lower temperature and its activity is destroyed at high temperature.
11. Refer Table 11 of this chapter.
12. Refer Table 22 of this chapter.
13. Homo poly saccharides are formed of only one type of monosa charides e.q. cellulose, starch, glycogen, incline, agar, xylan, araban etc. Heteropolysaccharide are formed of two or more type of monosecharides or this derivatives like amino sugars. Example-chitin, hyaluronic acid, peptidoglycon.
14. Refer Table 14 of this chapter.
15. Refer Table 6 of this chapter.
16. Refer Deoxyribose nucleic acid (DNA)' in 'Nuckeuc acids' of this chapter.

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CHAPTER 10 : CELL CYCLE AND CELL DIVISION

1. As in interphase, the cell prepares itself for cell division by biosynthesis of RNAs, proteins, DNA, energy molecules, etc.
2. G_0 phase is the state of arrested metabolism.
3. Exchange of genetic material between non-sister chromatids of homologous chromosomes is called crossing over.
4. Mitosis.
5. Kinetochore is disc-like area on the surface of centromere and is site of attachement of spindle fibre.
6. (i) During S-phase, DNA replication and biosynthesis of histones occur.
   (ii) During G_2-phase, RNAs and spindle proteins are synthesized and duplication of mitochondria, plastids and centrioles occurs.
7. Synaptonemal complex is a network of nucleoproteinous fibres present between the homologous chromosomes. It helps in synapsis of homologous chromosomes.
8. (i) It helps in growth and development.
   (ii) It helps in repair and regeneration.
9. Mitotic apparatus is formed of **two asters** (one at each pole) and two types of spindle fibres: **Chromosomal fibres** and **interpolar fibres.**
10. (i) In Metaphase of mitosis, the chromosomes arrange in one equatorial plate, while in metaphase-I of meiosis, bivalents are arranged in two equatorial plates.
    (ii) In metaphase of mitosis each chromosome is attached by two chromosomal fibres while in metaphase-I, each chromosome is attached by one chromosomal fibre.
11. (i) Zygotene: Pairing of homologous chromosomes, called **synapsis.**
    (ii) Pachytene: Crossing over between non-sister chromatids of homologous chromosomes.
    (iii) Anaphase-I : Separation of homologous chromosomes called dysjunction.
12. (i) Produces haploid gametes for sexual reproduction.
    (ii) Produces new combination of genes so produces variability which help in evolution and improvement of races.
    (iii) Proves interrelationship between organisms.

13. Prophase of mitosis is longest duration and involves:
    (i) Formation of asters by development of astral rays around the centrioles.
    (ii) Condensation of chromatin fibres into chromosomes by dehydration and spiralization.
    (iii) Disappearance of nuclear membrane and nucleolus.
    (iv) Formation of spindle fibres due to polymerization of dimeric tubulin molecules. Spindle fibres form a barrel shaped spindle with central equator and poles at its ends.

    Refer Fig. 3-C of chapter-10

14. (i) **Desynapsis** : Diplotene.
    (ii) **Disappearance of synaptonemal complex;** Pachytene.
    (iii) **Reduction of amount of DNA** per chromosome: Anaphase-II.

15. (i) **Metaphase plate.** Equator of the spindle formed during cell division is called **metaphase plate**. During metaphase of mitosis, the chromosomes arrange in one metaphase plate in such a way that their chromosomes lie at equator and arms are directed towards poles.
    (ii) **Control of mitosis:** It occurs at S-phase of interphase and is triggered by DNA replication which changes the nucleo-cytoplasmic ratio in the growing cell. Cell division maintains equilibrium between the nuclear mass and cytoplasmic mass, called **nucleoplasmic index.**

16. **Prophase-I** is of longest duration and is formed of five subphases:
    (i) **Leptotene** is characterized by **formation of asters** due to formation of astral rays around the centrioles, and beginning of **condensation of chromatin fibres** by dehydration and spirallization.
    (ii) **Zygotene** is characterized by **synapsis** of homologous chromosomes due to formation of an electron microscopic **synaptonemal complex** between homologous chromosomes and formation of bivalents.
    (iii) **Pachytene** is characterized by **tetrad formation** and crossing over between non-sister chromatids of homologus chromosomes in the presence of recombinase enzyme.
    (iv) **Diplotene** involves **desynapsis** (i.e. separation of homologous chromosomes), **terminalisation** (i.e. moving of chiasmata towards the ends of chromosomes) and beginning of disappearance of nuclear membrane and nucleolus.
    (v) **Diakinesis** is characterized by complete disappearance of nuclear membrane and nucleolus; completion of spindle formation and terminalization.

    Refer Fig. 13-A, B, C, D and E of chapter-10